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- GAS IN ATTACK. -
AND
- GAS IN DEFENSE. -

By

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GAS IN ATTACK.

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Carrying out a gas attack is the most technical-most dangerous-of war's problems, not alone to those taking part in it, as in the case of airplane work, but also to all friendly troops for miles around. The German High Command, realizing that and also the value of highly trained, technical men, turned the job of running their first gas attack over to two noted chemists-Professors Nerst and Haber. The result was a tremendous success so far as the gas attack was concerned, but "the patient died."

Gas is a new weapon and notwithstanding so many advances in science the world is still full of "it can't be done" experts in standardized methods of warfare.

Progress means work, means worry, and breaks up the easy routine of the "stand pat" soldier. And these "stand pat" soldiers are not all of the swivel chair variety either. They are found in even greater proportion in McClellan saddles and among the dough-boys on foot. As between the purely laboratory scientists and bigoted commander who can conceive of nothing new and who has no use for scientists, there is little to choose. The soldier who can combine both science and action is the one who wins world victories. When a Napoleon arises with the nerve to try new things the very first time on the scale they deserve to be tried, the world stands amazed. But how few of our commanders ever get these facts thoroughly into their heads.

REASON FOR GERMAN FAILURE AT YPRES, APRIL 1915.

The Germans had the first Ypres attack in preparation for several months. They had tried out the gas and the machinery for discharging it until they felt sure it would work successfully. These trials were of course witnessed by chemists, engineers and other scientists, and general staff officers and other notables who would have to pass on how, when and where to use the gas, or to command the troops supporting the attack.

And right there was the beginning of failure. Right there scoffers "and it can't be done" experts in established methods of warfare laid the foundations of failure. If those jinxes had all been in the German Army the Allies would have won hands down in nine months, but they were not, and worse still, they are not.

That yellowish green haze of chlorine drifting on a beautiful spring day in 1915 over the blooming fields of northern France exacted from gasping, terror-stricken soldiers a heavier toll of death

than war ever before or since has taken in the same space of time from an equal number of men.

Every man in the path of that greenish haze was dead or dying for miles back of the line and a terrible fear gripped the hearts and blanched the faces of veterans who knew cholera, the cobra, the stealth of the East, and the stifling sun of India.

What was the gas? For they knew it was a gas. How much more was ready to be turned loose? Where would the blow fall next? These were the immediate burning issues with the Allies.

At the same time we can imagine German Generals moving up to support the gas with an "I told you so" attitude, expecting to meet the accustomed fierce resistance they had learned to expect from the Canadian.

Haltingly, doubtingly, they moved on until lack of resistance convinced even those doubting Thomases that they could go through. Too Late! Brave men from north and south were rushing forward undismayed by this new monster that searched out and filled dugouts, deep trenches, and all other places theretofore safe against man's most powerful weapons. Yes, the next day was too late. Frenchman and Briton had again closed the road, nevermore to be opened. And the most stupendous change in warfare since gunpowder was invented had come, and come to stay. Let us not forget that.

GAS WARFARE TO CONTINUE.

No action of the United States in cutting out such a service will deter other peoples from carrying it on and further developing it. Indeed, no agreement among Nations will do this. If this were not true then wars would be no more, since every war is the outcome of a broken agreement. With the results of this war before it, any nation deciding to go to war hereafter will do so knowing that it must win or be forever crushed. That being the case, it will organize every means to win a decision and, knowing the extreme effectiveness of gas, will carry on gas warfare, particularly if the nation it decides to make war upon is not prepared for gas.

Moreover, researches into poisonous gases cannot be suppressed. Why? Because they can be carried on in out-of-the-way cellar rooms, where complete plans may be worked out to change existing industrial chemical plants into full capacity poisonous gas plants on a fortnight's notice, and who will be the wiser?

REASON FOR GERMAN DECISION TO USE GAS.

Reverting again to the attack at Ypres one naturally wonders what induced the German to start the use of gas. The answer is simple. His bloody repulse on the western front in the fall of 1914.

Finding the road to Dunkerque, Calais and Boulogne blocked by the French and English, and feeling that he could not unblock it by any

methods of war then in use, he cast about for something new and terrible. If he could find such a weapon and completely surprise the Allies, he felt he could still win the war easily.

For years the German had been the unchallenged master in the world of chemistry. No one else had any realization of the great world he controlled. But even at that time chemistry was common enough so that every high school boy had smelled chlorine and knew a whiff was enough and that a few full breaths meant death.

Before the war started chlorine was manufactured and used on a tremendous scale in chemical works, for bleaching paper, and for a thousand and one other uses. Even the gold industry took huge quantities in its reduction processes, while its value in purifying water was known to every water works engineer.

GERMAN CHOICE OF GAS.

No wonder the German chose chlorine. It fulfilled all his requirements. It was deadly, it was quite easily liquefied, it was already produced in large quantities from salt, of which he had an abundance, while methods of keeping and transporting it had been fully developed.

It should be stated here that all gases must be liquefied when taken to the battle line since enough transportation could not possibly be obtained to transport true gases to the front in the quantities needed. As Chlorine boils about 33 degrees below zero it develops considerable pressure at ordinary temperatures. For containers the German used the common commercial chlorine cylinder, about three feet long and holding some 45 pounds of gas, the filled cylinder weighing about 90 pounds. The cylinders used by the Allies later held about a third more gas and weighed when full about 140 pounds.

ADAPTION OF COMMERCIAL CHLORINE CYLINDERS.

The German had, however, to add one new feature to his cylinder. If he let the gas escape through an ordinary outlet the expanding gas would so cool the empty portion in the top of the cylinder as to slow down tremendously the escape of the remainder of the gas. The arrangement for overcoming this is exceedingly simple but nevertheless ingenious. It consists in so increasing the length of the outlet tube on the inside that it reaches almost to the bottom of the cylinder. When the outlet valve is opened the liquid chlorine is forced from the bottom of the cylinder by a little gas forming in the top and thence into the air through a discharge pipe extending over the parapet.

The liquid turns to gas as soon as it escapes from the end of the discharge pipe, where the cooling affects only the outside air and not the cylinder of chlorine, as would be the case if the outlet tube did not reach to the bottom of the cylinder.

These cloud gas cylinders were heavy and unwieldy and hence

it took time and a lot of effort to get up to the front line the hundreds needed for a gas attack. The Boche used enough cylinders to allow approximately one every yard along the front of attack. To protect them from observation and consequently from shrapnel and high explosive he placed them in holes or short trenches under the parapet just far enough to keep the top below the surface. He then covered them with two or three layers of sand bags. The Allies put their cylinders at the very bottom of the trench under the firing step on which the men stood when firing with the rifle.

DIFFICULTIES IN PREPARING CLOUD GAS ATTACKS.

This was a lot of labor and accordingly a cloud gas attack took a great deal of time to prepare. Moreover, since chlorine drifts with the wind and is no respecter of persons, it will kill friend and foe alike when it reaches them. The operator must wait until the wind blows directly toward the enemy and is neither too strong nor too weak; three to four miles per hour is the best. Too low a wind is dangerous, as it indicates instability and possible reversal so as to blow the gas back. The Germans had a disastrous experience of this sort at Hulluch, Flanders, in the spring of 1916, when the change of the wind near the end of the attack blew the gas back and caused 1100 casualties among his own troops. Too great a wind carries the gas away from the cylinders so rapidly that a deadly concentration cannot be produced.

It is thus evident that the first attack at Ypres was no light task even for the Boche, and accordingly its success was a real triumph for the scientist.

REASONS FOR PUTTING GAS IN ARTILLERY SHELL.

However, even at that early date the German undoubtedly realized that he could not carry out cloud gas attacks very often and probably hoped to win the war by the first one at Ypres. As we have seen, all he lacked to win by that attack was the nerve to follow it up with the necessary force of infantry, artillery and other troops. When he studied that failure, after learning of the casualties he had caused, he must have appreciated that the war was going to continue for a long time, and that even if gas could not thereafter be expected to bring about immediate victory it was too valuable an agent for producing casualties to be ignored.

As we have observed, gas is borne on the wind, and being no respecter of persons, may be a danger to friend and foe alike when it is liberated from front line trenches. The Boche knowing this and looking ahead for a year or two of war, reasoned that if the gas could be thrown in shells a considerable distance, he need not worry for fear it would be blown back on himself, even should the wind change. By properly regulating the distance to which he fired the gas and the amount he put over, he could carry out a gas attack with artillery when the wind

was actually blowing toward his own lines.

Thus we see that by the beginning of 1916 he was using tear or lachrymatory gases in artillery shell. Although these did not kill, they temporarily blinded the enemy and interfered very seriously with the service of artillery, and indeed any kind of service until the use of gas proof goggles become general. The English early furnished large numbers of these goggles to their troops, but by 1917 their issue was stopped entirely because tear gases were by that time often accompanied by deadly varieties, and goggles were of the same order of protection that the sand over an ostrich's head is to the rest of the ostrich.

Phosgene was the first poisonous gas used in shell and was begun by the Germans some time after they began using tear gases in shell. It has a boiling point about 80 degrees F., higher than chlorine, making it fairly easy to liquefy and use in artillery shells without inducing excessive pressure even during hot weather.

INVENTION OF LIVENS PROJECTOR.

The English in their first gas attack in retaliation against the Germans used chlorine in the exact manner in which it was used by the Germans. They later followed the Germans in the use of gas in artillery shell in much the same way. A little later still, however, they developed the Livens projector, a crude trench mortar for throwing over large quantities of gas and getting high concentrations directly on the points of attack. With the invention of the Livens projector the Allies began to take the lead in gas warfare and at the end were beginning completely to dominate the gas situation.

LOSSES DUE TO GAS ATTACKS.

Just what was the total percentage of losses from gas among the Allies as a whole is not known. With the Americans this loss reached nearly 30 percent, which, based on the latest casualty reports, amounts to about 75,000.

Thus gas alone in the comparatively small way in which the Germans used it caused nearly 3 out of every 10 casualties occurring among American troops. And yet those troops were thoroughly equipped with masks and as well trained as was possible in the time available. Considering that within six months we would have used gas five times as much as the Germans had ever used it, we can readily conceive what a powerful instrument of war gas has become.

While gas alone got three casualties, rifles, machine guns, shrapnel, high explosive shell, tanks, airplane bombs, hand grenades and bayonets got only seven. In other words, gas alone was nearly half as effective in producing casualties as all other forms of warfare put together.

There is a popular notion that gas warfare is the most horrible method of warfare ever invented and that it will be abolished because it is so horrible. And yet it is not horrible! Indeed it is far from being the most horrible form of warfare invented, provided both sides are prepared defensively and offensively, and yet against an unprepared army gas is the deadliest weapon man has ever tried in war. With modern highly poisonous gases, coupled with modern methods of using them, no army unprepared for gas can exist for a day against an army thoroughly equipped for using it.

Considering again the question of horribleness, medical records show that out of every 100 men gassed only three or four die, and so far as records of four years show, very few are permanently injured, - startling as this statement may seem in comparison with the widely published statements concerning the horribleness of gas. The lung appears to have much the same facility for curing injuries from gas as the skin has for curing itself against cuts and bruises. But what about high explosive? Out of every 100 casualties from all forms of warfare other than gas between 20 and 25 die, while from one to two more are maimed, blinded or disfigured for life. Thus in the percentage of deaths and permanent injuries gas is only one-sixth to one-seventh as deadly as other forms of warfare.

GASE COMPLEMENTARY TO OTHER FORMS OF WARFARE.

Looking at it from another angle, gas fits in perfectly with all other forms of fighting. Being heavier than air and being carried by the wind, it seeks out and fills up all holes, trenches and ravines, and lingers among groups of buildings and in woods where the force of the wind is broken or does not exist at all. Now long before gas was thought of every rookie knew that deep trenches, dugouts, woods and ravines were a more or less complete protection against bullets, high explosives and shrapnel. These, however, are just the places where gas is most effective. The safety zones for other forms of warfare become death traps for gas.

GAS WARFARE HUMANE.

We have touched heretofore only on the deadly forms of gas, though there is a very large number of gases which may all be grouped under the head of irritants.

While some effect the nose and throat, and others attack the eyes, all are effective in extremely low concentrations and make life miserable or vision impossible to those without a mask. Yet they do not kill. They are used in armies thoroughly equipped with gas for economy, because they force the wearing of the mask with very small expenditures of ammunition. These irritants may be used to attack savages

or bands of men unequipped with masks, who can thus be routed or captured while causing very few casualties among them, if that be desirable.

Thus instead of gas warfare being the most horrible it is the most humane where both sides are prepared for it, while against savages or unprepared peoples it can be made so humane that but few casualties will result.

DEVELOPMENTS IN THE FUTURE.

Just as developments in masks have gone on in the past just so will they go on in the future. Just as from time to time gases were found that broke down or penetrated existing masks, just so in future will gases be found that will more or less break down or penetrate the best existing masks. Accordingly, for thorough preparation mask development must be kept absolutely parallel with development in poisonous and irritating gases. Mask development cannot, however, be kept parallel unless those working on masks know exactly what is going on in the development of poisonous gases. Thus a nation that stops all investigation into poisonous gases cannot hope to be prepared on the defensive side should the time ever come when defense against gas is needed.

NEED FOR A WIDE RANGE OF INFORMATION.

The Chemical Warfare Service in France learned quite early that it dared not depend upon the statements of a single individual in a matter of great importance unless that particular individual had been highly trained in weighing data before him, and, in a special case, had possessed exceptional opportunities for obtaining those data either by personal observation, at by oral interview or by reading.

Thus when mustard gas had been used nearly two months and had caused such heavy casualties among the British that they were seriously worried over it, an officer high in their service stated that since they had learned to recognize it and how to protect themselves against it, it had ceased to cause them any worry. In fact, he wondered why the Germans persisted in its use. A little later a French officer having a limited viewpoint gave somewhat similar misinformation, but the Chemical Warfare Service, having far better information, was not deceived by those statements. This incident is cited because it is believed highly important that Staff Officers and others who must pass on important problems should realize that the individual with a narrow viewpoint, or one who has seen but very little of the field of operations, is not to be depended upon when drawing conclusions on matters as vital as war.

GAS TACTICS - GENERAL.

In the broadest terms, gas can be used for four purposes: (1) When it is desired to produce deaths or lesser casualties in front line

and closely supporting trenches just prior to an advance. In this case the gas must be one that is quickly dissipated or else the troops must charge through their own gas. As masks become more perfect and more comfortable, this appears to be a possibility worthy of the most careful consideration in every plan of attack. (2) When it is desired to produce casualties in front line trenches, among supports, reserves and all other personnel at places where an attack is expected to be made within a few hours, say 3 to 12. This allows considerably more latitude in the choice of gases and still permits making the advance after the gases have become dissipated sufficiently to be safe without masks. (3) When it is desired to obtain casualties in front line trenches among the supports and reserves and along lines of communication, in concentration camps, rest areas and cross roads, to the limit of range of artillery, when no attack is planned or when the attack will not take place for several days. Such conditions permit the use of all known gases, the time allowed before an advance, of course, being sufficient for the clearing away of each particular gas used. (4) When it is desired to reach training areas, cantonments, railway junctions and places beyond the reach of guns and which can only be reached by airplane or balloons. The use of gas by such methods has not yet been undertaken by any army, but there is no tactical reason why it should not be.

GASES TO BE USED.

Gases are divided into three general groups so far as tactical uses are concerned.

(a) Persistent. Mustard gas (dichlorethylsulphide) is the king and type. Mustard gas is in a class by itself, due to its great persistency, to its effectiveness in very low concentrations, and to the fact that it affects the skin, the eyes, the throat and lungs, as well as the digestive tract if food be eaten that has been exposed to it. Some lachrymators are practically as persistent.

(b) Non-Persistent. These gases are highly lethal (deadly) with low persistency. The group includes phosgene, cyanogen chloride, chlorine, diphosgene, and others of a similar nature. Chloropicrin is in the same class, though more persistent than any of the others.

(c) Lachrymatory and Irritating Gases. These include bromacetone, ethyl iodoacetate, brombenzylcyanide, and several other lachrymators, and diphenyl chlorarsine, or sneezing gas. All of these, while highly irritating or lachrymatory, are not lethal, except in extremely high concentrations seldom attained in the field. Lachrymators are highly economical in forcing the wearing of the mask and are used for that purpose.

So much for what gas has done and may yet do. Let us now see what methods have been adopted, what machines have been developed, and what training of troops has been necessary in the past to bring about the results stated.

RETROSPECTIVE.

So far as we know the first attack at Ypres continued for about 45 minutes. Whether this was due to small discharge pipes or to the discharge of a number of cylinders one after the other is not known. When the value of a high concentration was realized the duration of the attack was shortened and the number of cylinders per 100 yards increased so as to give a high concentration. This development went on to the end of hostilities when consideration was being given to cylinders that could be discharged in two or three minutes.

As noted previously, within two or three days after that first gas attack British troops were equipped with crude but fairly effective protection against chlorine, while as time went on better masks were invented and armies were better trained in accurate and quick adjustment of these masks. Alarm signals were developed and sentries trained to note any cloud appearing over the enemy's trenches, to recognize the hissing of gas escaping from a cylinder, to listen for unusual sounds of hammering, which might denote preparation for a gas attack, and finally to give the alarm to others. As these precautions tended to reduce casualties, it was necessary to develop new methods of attack or losses would have been so reduced as to make a cloud attack not worth the effort required to carry it out.

IMPROVED METHODS OF ATTACK.

As better methods of attack were developed heavy losses continued although nothing in comparison with those in the first attack where there was complete surprise and no protection. The duration of the attack was shortened and the number of cylinders increased, both factors tending to increase the concentration of gas. At the same time attacks began to be made at night since night is particularly favorable to gas attacks. In the first place, men cannot see the gas cloud, nor can they see to move about, to adjust the mask, or to do a number of other things necessary to prevent gas casualties. In the second place men are sleepy and tired. Some become careless while others become confused and panicky. Consequently a gas cloud sweeping over trenches always gets some casualties.

One development was to make attacks discontinuous, that is, gas would be liberated for 20 minutes then 3 or 4 hours be allowed to elapse and gas liberated again for 15 to 20 minutes. The first time this was tried it was naturally quite successful for the reason that troops up to that time had experienced but one wave of gas in each attack and hence when the first wave passed over they felt safe for the rest of the night. The second wave took its toll of deaths accordingly. This discontinuous method of attack had an important result other than just the number of casualties produced. It caused unrest and uneasiness and necessitated taking the greatest precautions throughout the rest of the night.

VISIBILITY OF GAS CLOUD.

Inasmuch as any large quantity of gas liberated produces a cloud, especially at night, through cooling and condensation of the air, the standard method of detecting a cloud gas attack was to keep a sharp lookout for anything resembling a whitish mist appearing over the enemy's trenches.

The enemy took advantage of this to set off phosphorus and other smoke materials to simulate a real gas attack. This simulation of a gas attack had peculiar advantages of its own. In early gas attacks troops were taught to adjust their masks, to stop all movement at the approach of the cloud, and to remain perfectly still until the cloud had passed. Naturally the first smoke clouds forced the adjustment of the mask and the stoppage of all movement. In fact men sat down on the firing step and otherwise made themselves comfortable, there being no thought of preparation for repelling an attack. Consequently the attacking troops following right in the edge of the smoke cloud took the men with masks on at a terrific disadvantage.

Many other expedients were used to make these gas attacks a success. A light drizzle or a fog became a very popular screen for a gas attack. Likewise, since all masks are more or less uncomfortable and warm, advantage was taken of hot sultry nights to increase the discomfort of the troops. The heavy air also kept the gas close to the ground and thus prolonged the deadly concentration in trenches, woods, or dugouts.

SPREAD OF GAS CLOUD.

As has been indicated the visible portion of a gas cloud is generally about 30 feet in height and while unquestionably poisonous gas rises somewhat higher the distance is not very great. As to the spread of the gas cloud, it was realized even when planning the first gas attacks that cylinders could not be equally spaced due to the irregularity of the trenches and to variations in the ground itself. Accordingly cylinders were placed in groups with vacant spaces between. Since in the early days these groups were fairly close together the spread of the gases brought them in touch before reaching the enemy line. Later when the British were contemplating setting off gas clouds from cylinders on trench railway cars, it became quite desirable to know how fast the gas spread, in order to determine beforehand how far apart the groups of cars holding the cylinders could be placed. Investigations carried out by both the British and Americans showed that the angle of spread of the gas, considering it emitted at a point, is between 20 and 25 degrees. The degree of spread depends somewhat upon atmospheric conditions, being less or greater according as the velocity of the wind is high or low. This angle of spread was verified from the examination of airplane photographs of cloud gas attacks which showed vegetation that had been killed by the

gas cloud. This spread is very much more uniform than would be expected and may be taken safely as 20 degrees when desiring to be sure the separated clouds of gas will mingle properly over the enemy trenches.

Very early in the war, probably before their first gas attack, the Germans decided that the wind must be making an angle of at least 40 degrees with their own line of trenches before they would allow the discharge of gas. The British at first required the angle to be about 45 degrees. A study of the above data in regard to the dispersion of gas in a horizontal direction shows that the British and German requirements gave a safety zone of 25 to 30 degrees between the natural spread of the gas and the line of trenches. This safety zone was necessary because the gas will naturally eddy with every current of air and moreover, since it hugs the ground closely, any irregularity of the surface is apt to deflect it. A realization of these facts helps one to understand how projectors which threw gas nearly a mile from the front line were so desirable, since with them a projector attack can be made when the angle of safety of the wind is reduced to almost nothing.

REASONS FOR DESIRING A HIGH CONCENTRATION OF GAS.

It should be remarked here that a high concentration of gas is desirable, not alone because it is deadly at the front line trenches, but because it carries so much farther over the support and reserve trenches. Every high school boy who has studied chemistry knows that all gases tend to mingle with each other regardless of the difference in the specific gravities of the gases. Consequently a gas cloud becomes weaker (that is the concentration decreases steadily) with the time. With heavy gases that remain close to the ground this diffusion is much slower than with light gases, which tend to rise and thus increase diffusion by mechanical mixing. Accordingly a high concentration will carry a dangerous concentration much farther than a low one, but just how much farther it is impossible to say. The British claim to have actually had casualties 45 kilometers (28 miles) back of the line where the gas attack was made. At any rate, it was well recognized before hostilities ceased that cloud gas attacks would undoubtedly be dangerous 10 to 12 miles back in localities favorable to the attack.

As will be inferred from the statement that all poisonous gases average about three times as heavy as air, they tend to roll into and to remain in narrow valleys. If such valleys have fairly smooth surfaces and the wind be blowing directly up or down them the cloud of gas will be carried the maximum distance.

During the war there were several cases where troops on knolls or high points of land were nearly immune from a gas attack while those in low places in the valleys close by suffered severely.

HEIGHT OF GAS CLOUD.

It was early known that pigeons would fly through a gas attack, although they were apparently as susceptible to gas as a man himself. It was probably some time before it was realized that they did not fly a long distance through the cloud, but by rising a short distance (50 feet is probably enough) they got above dangerous concentration of gas. In fact, all observations tend to confirm the theory that a gas cloud does not rise much higher than 30 feet above the ground. Certainly this is true of the visible part of the cloud, though concentrations that are dangerous but not visible may rise, still higher.

These gas clouds have another very important effect. Chlorine and phosgene, the principal gases used in cloud attack, are highly corrosive of copper or brass and to only a slightly lesser extent of unprotected steel. Thus it was soon found that within 15 minutes machine guns would jam and rifles stick if a slow fire were not kept up. This was due to the corrosion not only of the steel of the machine gun and the rifle but even more to the corrosion of the brass shell of the ammunition. Accordingly, following every cloud gas attack it was necessary first to wash with carbonate of soda water all ammunition that had been exposed to the attack, and second, to thoroughly grease or oil it. Even then it was considered highly desirable to take the very first opportunity of firing the corroded ammunition.

CLOUD GAS NOT OBSOLETE.

Many people were of the impression at the time we entered the war that cloud gas was obsolete. This was an entirely erroneous idea, which probably arose from the fact that gas attacks by artillery were even then far more frequent than cloud gas attacks. The reason for the greater number of attacks by artillery was not that those attacks were more effective, but that cloud gas attacks carried out under the old conditions were very difficult and laborious to prepare, besides being dangerous to execute. Moreover, after the cylinders were in place there was often a long period of waiting for the wind to be right.

During this time the trenches prepared for gas were subject to raids and gas cylinders to destruction by artillery fire if discovered. Indeed, it was some time after gas was introduced that organized raids became the standard method of obtaining information of what was going on in the front line, and to a large extent of what was going on back of that line. By means of putting a box barrage around a section of a trench it was possible at almost any time for either side to capture a trench and hold it long enough to thoroughly explore every part of it. The American Gas Service looked at these facts from unprejudiced point of view. Inasmuch as a cloud attack was so terrible

when successful they felt it should be continued.

ORGANIZATION OF THE CHEMICAL WARFARE SERVICE.

Since no plan whatever was provided for chemical warfare when that service was organized in France, the Commander-in-Chief wisely permitted a wide latitude in its formation. Thus it was that the Chemical Warfare Service in France, as well as that organized nine months later in the United States, including research, development, production and supply, training in gas defense, chemical warfare intelligence, and the actual training, equipping and operating of gas troops. These later of course were handled in battle by the Chemical Warfare Service entirely in accord with and under orders of the commanding general of the armies, corps, and divisions with which they were operating. This was a very fortunate organization. It permitted the widest latitude in using the personnel obtained to the best advantage, and in realizing very early the gas and gas defense needs of all other troops at the front. In fact, with its knowledge of gases and gas warfare, the Chemical Warfare Service was enabled in nearly every case to realize the needs of the man at the front long before he realized them himself. It is believed that this is the soundest kind of organization, for the reason that it binds into intimate contact research, supply, experiment, intelligence, development and actual fighting. The Chemical Warfare Service as organized in France had five subdivisions—Offense, Defense, Technical, Supply, and Intelligence. Experience indicated that Offense and Defense should be merged and that Training should be separate. These changes and other minor ones to adapt the organization to the regular General Staff organization appears to be the ideal, and was what the Chemical Warfare Service was working toward when the war closed.

GAS TROOPS ECONOMICAL.

The first project for American Expeditionary Forces called for one regiment of six companies of gas troops, to be organized under the Corps of Engineers. This was felt by the Chemical Warfare Service in France to be absurdly small. However, no arguments of the Chemical Warfare Service could get this number of gas troops increased until (a) the effectiveness of the enemy's gas has been thoroughly demonstrated by dead and wounded Americans, and (b) the value of our own gas troops had been demonstrated in action. The authorized number was then increased ninefold; that is, from six companies to 54 companies, formed into three regiments of six battalions each.

Gas troops are used for economy. As previously noted, the gas in the new mobile gas cylinders is more than 50 per cent of the total weight of the filled cylinder. Likewise 50 per cent of the Livens bombs, or drums as they are usually but inaptly called, is liquid gas. Even the Stokes mortar bomb in the crude shape, used throughout the war,

was 30 per cent liquid gas.

On the other hand, artillery shell contains at the most only about 12 per cent gas. This last does not include the powder charge nor in the case of fixed ammunition the weight of the cartridge case. Again, while the artillery gun is an expensive and more or less complicated machine, requiring highly skilled personnel, the cylinders and mortars used by gas troops are exceedingly simple of construction and require no great skill in operation.

For these reasons gas operations with gas troops are about five times as efficient as gas operations with artillery shell up to the limit of range of the weapons used. Accordingly, gas troops are fundamentally economical of men, material, and transportation. However, as the range of their guns is short - only about one mile - every effort was being made at the time of the armistice to increase it to 3000 yards for at least a portion of the equipment. Experiments up to the time of the armistice indicated that this would not be a very difficult task to accomplish.

Gas is the most technical substance used in warfare in the front line, either for attack or defense. Being so highly technical it gives more chances to exercise skill and ingenuity than other forms of warfare.

GAS TROOPS SHOULD REPLACE ALL TRENCH MORTAR TROOPS.

The American gas troops used not only poisonous gases but phosphorus, thermite and high explosive.

In all the offensive fighting, from the Marne until the armistice, gas troops did more work with essentially trench mortar materials than many of the trench mortar troops themselves. The guns or mortars used by them for firing gas can be used equally well to fire high explosive and incendiary materials. Consequently in training gas troops to handle gas they are trained to handle all other trench warfare ammunition.

Furthermore, since gas on an average gets casualties with a less expenditure of ammunition than any other form of warfare yet invented, it is evident that all trench mortar work should include firing of gas whenever possible. As a matter of fact, the phrase "trench warfare" is unfortunate. It brings to mind the conditions of stalemate that existed for three years on the western battle front in France. Our troops never have been, and it is hoped never will be, led into the error of considering trench warfare as anything but a momentary proposition.

It was with this thought in mind that all plans for gas troops and gas material were arranged for offensive warfare, that is, warfare of movement. For these reasons there should be sufficient gas troops to do all trench warfare work and trench warfare organizations as such, omitted from the army.

HIGH EXPLOSIVES - LIVENS BOMBS.

In connection with the above recommendation that gas troops should replace all trench mortar troops, the Chemical Warfare Service took up the use of high explosive bombs fired from Livens projectors. For this purpose the ordinary Livens bomb for poisonous gas was converted by drilling an extra hole and threading it for a steel plug. Through this hole the bomb was filled with 30 pounds of T.N.T. at the gas experimental field, 60 miles from St. Mihiel salient. Two methods for filling were used. The first and principal one was to put the granular T.N.T. into the drum and ram it with a stick; the second method was to melt the T.N.T. and cast it. the latter method was too complicated to make advisable its continuance in the field, especially as T.N.T. in granular form was found absolutely safe from premature explosion. These T.N.T. bombs proved highly popular with the infantry and were apparently correspondingly unpopular with the enemy. The bombs being cylindrical, with hemispherical ends, did not sink into the ground upon striking unless the ground was very soft. While they were fired simultaneously in groups of 20 to 100 against wire entanglements or strong points, the number of bombs fired at one time can be increased to any extent deemed advisable. It was found that 20 to 100 of these leveled everything above the ground in the vicinity of the explosion.

A noted example was their use in the reduction of the St. Mihiel salient. One of the objectives was the famous Cote des Eparges, which the French had failed to capture in 1915. This hill was found to contain a number of machine guns and minenwerfer emplacements. The gas officers in command of the companies of the First Gas Regiment assigned to the Fifth United States Army Corps proposed to attack this hill with 100 projectors filled with T.N.T. The French Chief of Artillery readily assented to this. Notwithstanding the projectors were installed in a rainstorm under heavy fire from minenwerfer and 77-millimeter guns, the projectors were successfully installed. The simultaneous explosion of these 100 bombs of T.N.T. wiped out opposition on the crescent of the hill so completely that the attacking infantry were able to pass the Cote des Eparges before they suffered a single casualty.

USE OF PHOSPHORUS AND THERMITE.

Phosphorus and thermite were used to attack the personnel of machine gun nests and drive them away from their guns. This work was performed with the greatest success by all companies of the Gas Regiment, beginning with the Allies' counter offensive in the latter part of July, 1918, and lasting until the signing of the armistice. Immediately after the counter offensive started on July 18, 1918, the gas troops were assigned to road work. Losses from machine gun nests soon began to get serious, and upon their own request the gas troops

were allowed to try taking these machine guns with phosphorus and thermitite. These efforts were crowned with success. This work, coupled with the extensive use of smoke screens by gas troops, helped materially in getting the number of authorized gas troops increased from six companies to 54 companies. Phosphorus was used both for its moral effect and as a smoke screen in every battle from July to the end of the war. By that time its value was so appreciated that it was decided to have phosphorus shells furnished for three-inch Stokes mortars.

GAS TO ATTACK MACHINE GUN NESTS.

The four-inch Stokes mortar, due to its rapidity of fire, can get up a high concentration of gas rapidly, and was often so used. Its short range of about 1000 yards interfered in its use for gas. Accordingly, one of the problems that should be worked out is whether, with improved projectors and cylinders, it will not be best to do away with trying to use gas in four-inch Stokes mortars and, on account of its increased mobility, use only three-inch Stokes mortar for phosphorus, smoke and high explosive. Although it took herculean efforts on the part of the Gas Regiment, they succeeded in most places in the Argonne and St. Mihiel fights in keeping the four-inch Stokes mortar up with the advancing infantry until all ammunition for them was exhausted.

Thermitite is more spectacular than phosphorus. Its effect is largely a moral one, except in the case of a direct hit. This is because the molten thermitite spreads out and cools too rapidly for the best effect. Highly important results were promised by mixing slugs of iron with thermitite. These become nearly white hot and, retaining their heat, burn for a very much longer time than the molten thermitite. This scheme is worthy of very careful experiment and development.

SPHERE OF USEFULNESS OF GAS TROOPS.

As was proposed in France, Chemical Warfare Service troops using gas, smoke, incendiary materials and high explosives should be able to dominate the first mile and a half of No Man's Land. In fact, with mobile cylinders for cloud gas attacks mobile projectors with increased range and sufficient high explosive projectiles, it is believed that one gas company of 250 men can make it practically impossible for any considerable number of the enemy to congregate within 2500 or 3000 yards on a five-mile front.

Gas from projector attacks and from cloud gas attacks will penetrate very much farther than this and will cause casualties back several miles among troops who do not get their masks adjusted in time. However, due to the great improvement in masks and in gas defensive training, the only casualties that will occur after the gas alarm is given will be among men who get confused, who are asleep, or who have allowed their masks to be lost or injured.

GENERAL TACTICS OF GAS PROJECTORS.

The projectors as used in the war were of two lengths, 2 feet 9 inches and 4 feet. These gave a range of approximately 1700 and 2200 yards. The old projectors were simple drawn medium steel tubes of uniform cross section, with an inside diameter of 8 inches. The 2-foot 9-inch projector weighed about 100 pounds and the 4-foot projector about 140 pounds. Thus both sizes were too heavy for one man to carry. However, it has been shown that the weight of the 2-foot 9-inch projector can be decreased fully one-third its present weight by using nickel or other special steel. This will make it a one-man load.

Moreover, with a little lighter bomb and a better grade of powder the 2-foot 9-inch projector should give a range of 2200 to 2500 yards.

METHODS OF FIRING PROJECTORS.

The old method of firing projectors was to place them in a V-shaped trench deep enough to have the tops flush with the surface of the ground. Each was covered with a cap and the whole emplacement camouflaged during the daytime. Since the base plates are about 16 inches in diameter it required a lot of work to set or "dig in" a few hundred projectors. Experiments taken up early by the American Gas Service showed that these projectors could be fired by simply excavating a very shallow trench for the base plate. The muzzle was supported by crossed sticks or boards. The accuracy, using this method, was found to be fully equal to that of the projectors when dug in while the work of installing them was less than 25 per cent of that required by the old method. This method made it possible to install projectors in less than 25 per cent of the time required by the old method; i.e., within two or three hours, thereby enabling a gas company to make quite a large projector attack in one night. The projectors were fired simultaneously by connecting them up in series with ordinary blasting machines operated by hand from a convenient point in the rear. One of the future developments will be along the line of increasing the number of guns to be fired by one exploder.

SIZE OF PROJECTOR ATTACKS.

Some very large attacks have been made with these projectors. The British fired nearly 2500 at one time into Lens. The concentration of gas close to the bursting of a projector drum is terrific and will kill a man almost instantly if caught without his mask adjusted. Indeed, if the mask be in poor condition the high concentration obtained will readily penetrate it. The Germans feared these projector attacks more than any other form of gas attack used by the Allies. Indeed, so successful were they found that cylinders were never used by the Ameri-

can gas troops. However, as before stated, this was due to the weight of cylinders used and not to any doubt as to the efficiency of cloud gas attacks.

At Hartmansweilerkopf a very successful projector attack was carried out by the Americans. Due to the ability of the Americans to get a much larger number of projectors to this point than a French Gas Company in that vicinity, the Americans were given the job of making the attack. They installed 500 projectors, but to do so had to transport the projectors and all other material required, amounting to about 50 tons, together with 100 men, their equipment and tools, a distance of about 50 miles by truck. In making this 50 miles they crossed three mountain ranges, transported their material 1000 yards up a mountain on a cableway, packed it on mules for about two miles, and finally carried it by hand 600 yards to within 300 yards of the enemys front line. The installation was made in bright moonlight under a heavy minenwerfer fire from the hill. The attack was a decided success, and for the first time in some three years minenwerfers on that hill were silent for six days.

GASES USED IN PROJECTOR ATTACKS.

Phosgene is the gas principally used in Livens projectors. Chloropicrin is also often used, but it is not nearly so effective as phosgene, though it has considerably greater persistency. At the time of the armistice studies were being made looking toward the use of mustard gas and lachrymatory gases in a certain proportion of projector bombs. Undoubtedly this will be done in the future, especially in the form of high explosive mustard gas bombs. These latter will be referred to more fully under "Gas in Artillery Shell".

A great deal of study was given to the possible use of deceptive gases. One of these gases was tried out by Americans at St. Mihiel. In this particular case the gas had a highly offensive odor but was not poisonous. Of course, the idea is not to let the enemy know whether it is poisonous or not. He will thus be forced to wear the mask while the attacking troops, having no masks, can take him at a great disadvantage.

British troops carried out a very successful raid by firing an oil bought in Paris and known as "bone oil". It has a rather strong offensive odor but is in nowise poisonous. This oil was bought and filled into projector bombs in the field. The attack was so much of a success that the British, upon reaching the German trenches, found the soldiers sitting down or otherwise taking it quietly with their masks on. The Germans thought it was a regular projector attack with phosgene and that accordingly the English troops would not make an attack until the gas had dissipated.

DETECTING PROJECTOR ATTACKS.

While the powder charge in each projector is comparatively small, several hundred of them fired at one time produce a large flash of light and a heavy detonation. The enemy soon learned that this heavy flash of light at night meant a projector attack coming. Of, course, he did not know just where the projectors were going to land, but he provided for that contingency by having the alarm given wherever the flash of light could be seen. Masks were adjusted accordingly. The detonation was much less reliable than the flash of light as an indicator of a projector attack. For this reason a lot of study and experimentation was carried out by the Americans looking toward a reduction of the flash. This is accomplished to a considerable degree by properly proportioning the powder charge and also by the addition of certain chemicals to the powder charge. In the field use is made of woods or hills behind which the projectors are installed. In the same manner a careful search is made to find enemy forces with positions on the reverse slope of a hill where they will probably not perceive the flash of a projector attack made on their front.

The Germans made two very successful attacks against the Americans under these conditions. In one case men were in a wood just over the crest on the reverse slope of a hill and asleep in dugouts with a few or no sentinels about. The result was some 300 casualties, of whom 30 to 40 were deaths. The other attack was on an open hillside. Here again most of the Americans were back on the reverse slope of the hill with no sentries posted to look for just such attacks. The Germans in this case made use of a small hill for concealing their own projectors. This doubled the protection against the "flash" and caught the Americans quite by surprise. The Germans followed this particular projector attack in a very few minutes with a bombardment of high explosive and gas shells, which they kept up from about 2 a. m. until nearly 7 a. m. They got some 185 casualties, of whom about 25 were deaths. The high percentage of deaths was due to the inability of the Americans to evacuate the wounded during the bombardment. This bombardment produced additional casualties by throwing the men about and disarranging their masks while gas still lingered in the trenches.

DUMMY FLASHES.

As the gas organization increased in size and efficiency — every effort was being made to exercise all the ingenuity the American possessed. The Americans developed dummy flashes and used them so successfully that had the war continued their use would have become very general. By making a large use of them the enemy would be forced to constantly sound the gas alarm and take all the precautions necessary for a projector attack, even when there was no danger.

Among other expedients used to deceive the enemy was the fir-

ing of projectors during the daytime. The flash was not then visible, and by having artillery fired in co-operation, the detonation was not noticeable. Another interesting example of the value of not standardizing methods of attack is shown in the use of smoke in the Argonne fight. The German soon learned that a heavy smoke probably covered attacking troops. He accordingly adopted the habit of putting down a heavy barrage on or behind every smoke screen that appeared along the American line. As soon as this fact became apparent the tactics of the gas troops were changed, and for a time smoke screens were put up where there were no troops and the attack made elsewhere. Thus the German was kept guessing.

GAS IN ARTILLERY SHELL.

There are two general methods of firing gas shell, that for harassing and that for effect or destructive fire. Persistent gases are fired for both harassing and destruction, non-persistent gases usually for destruction and irritant gases usually for harassing purposes only.

As stated previously, gas troops are used for economy-economy in complicated weapons, economy in ammunition, and consequently economy in all transportation facilities required in battle. The artillery takes up gas attacks at the extreme limit of range reached by gas troops and throws gas from that point back into the enemy territory as far as the guns can reach. Occasionally artillery is used inside the zone covered by gas troops. This, however, is only in cases where extreme accuracy in firing is essential or occasionally where it may be very difficult to set up the weapons used by gas troops near enough to the front line to reach the point to be attacked. It is thus seen that artillery is used in making gas attacks solely to get range or exceptional accuracy.

All poisonous gases used in war are used in artillery projectiles with one important exception-chlorine. Chlorine is not used because it is very much less effective than other gases, besides generating too high a pressure in the shell during the heat of summer.

SHELL MARKINGS.

Economy, efficiency and simplicity are three of the most vital factors in successful warfare. These apply even more to gas than to other methods of wholesale murder.

For instance, the question of the markings on gas shells is highly important. Just as at first there was a tendency to multiply the numbers of gases used, just so there was a tendency to go into great detail with the gas markings on artillery shell.

The German was first to learn the necessity for simple markings. His scheme was to use a green cross for lethal shells (low persistent gases), blue cross for irritating and lachrymatory gases, and yellow cross for persistent gases. Even with such simple markings he

found it advisable where more than one class of shell was to be fired in an attack to pile those shells one on the top of the other in order to insure that they would be fired in the proper sequence. Thus in combining blue and green cross he always piled the blue cross on top.

GASES USED IN WAR.

Gases may be divided according to their characteristics into persistent, non-persistent and irritant. Another classification sometimes used is based on the effects of the gas on man, as lethal (deadly), vesicant (burning the skin), lachrymatory (affecting the eyes) and irritating (affecting the nose, throat and lungs, but not lethal). In this discussion they will generally be referred to as persistent, non-persistent and irritant.

MUSTARD GAS.

Mustard gas, called yperite by the French, is the king of all gases. It is estimated that more than 80 per cent of all gas casualties among the English and Americans was caused by this gas. Technically it is dichlorethylsulphide.

This gas was discovered by a German chemist, Victor Mayer, in 1886. He pursued his experiments until he saw that the gas was having as serious an effect upon his experimenters as upon the animals experimented with. At that stage he stopped.

It is interesting to note that an English chemist recommended the use of this gas a year before the Germans began using it. But here, as in the case of many other things, there was either too much fear, or hostility, or both, to new ideas, and once again the initiative was left to the German.

The gas is a yellowish oily fluid, freezing at about 50 degrees F. and boiling at about 422 degrees F. The color varies with the impurities and solvents in it. It appears to combine to a certain extent with the iron or steel in shells, because the mustard gas as seen sprayed on vegetation from bursting shells appears to vary from a fairly dark brown to almost tar black.

The modern method of making it is to agitate sulphurmonochloride vigorously in the presence of ethylene vapor.

The gas is highly persistent, that sprayed on the ground being dangerous from a minimum of about two days in warm dry weather to a week or even longer in damp, cold weather. It vaporizes very slowly. The idea will naturally occur that it must be effective in extremely low concentration or else its slow vaporization would make it useless. That idea is correct. It is claimed that the highest concentration of the gas that can be obtained at 68 degrees F. is about one part in 30,000 of air. It has, moreover, the quality of cumulative effect to a very marked degree, being fully 50 per cent even for very low concentration; for ex-

ample, if one part in 2,000,000 is breathed for 20 hours it will produce as serious a casualty as one part in 100,000 will produce in two hours; that is, if you multiply the time by 10 the concentration can be decreased to one-fifth and yet get the same result.

Mustard gas produces casualties almost wholly by burning. The theory is that the gas in the presence of moisture is broken up so as to liberate hydrochloric acid and that this acid produces the burn. The gas accordingly burns any soft moist tissue it reaches, whether inside or outside the body. Moreover, as it readily penetrates clothing, all soft parts of the skin are burned by the true gas, which is contrary to the original idea that burns were caused only by splashes of the liquid. Mustard gas has a not unpleasant odor, that of the Germans being somewhat like mustard and that of the Allies exactly like garlic. Finally the gas has a pronounced delayed action, its effects not being felt for 4 to 12 hours after exposure, during which time the person breathing it experiences no discomfort. It should also be added that after breathing the gas for 30 minutes to two hours, depending upon the person, the latter loses his sense of smell and can no longer detect the gas. As may be readily imagined these qualities make it highly valuable, or highly dangerous, depending upon which way you are looking at it. Indeed, as before said, it is the king of gases. It changed not alone gas warfare, but to a considerable extent all warfare.

Mustard gas shells were picked up and opened after the first attack against the British in July, 1917. The English extracted the gas and within 48 hours knew its composition. Within a week they had found in German chemistries Mayer's account of his discovery and laboratory methods for making it.

Notwithstanding an early realization of the importance of this gas and the determined efforts made to manufacture it on a large scale by the English, French, and Americans, it was almost eleven months after its first use by the Germans before the first Allied mustard gas attack took place. This was made by the French in the vicinity of Compiègne in June, 1918. Thus for eleven months the German had a tremendous advantage over the Allies. That he did not make a greater use of it was surprising to the Allies until just before the armistice, when it was learned that he had been making it by a cumbersome, slow and expensive method, and that his total production was only about six tons per day.

It is interesting to note that before the armistice was signed the Americans actually made 40 tons in one day and were equipped to make 80 tons but had not the shell in which to put it.

HOW USED

Mustard gas can be used in all artillery shell from three-inch to the largest guns built. Up to the present, due to its persistent nature gas has found its greatest use on the defensive or stabilized fronts. It is very powerful as a harassing agent. Comparatively small quantities

of it will force constant wearing of the mask and the running of separate reliefs to any position that must be held. In an attack it is used on the flanks to prevent counter attack from those places or to make attempts to counter attack difficult. It is used against strong points, such as woods, villages and small fortifications in the zone of advance but which it is not proposed to enter during the attack. The enemy is thus forced to evacuate these places unless he can run reliefs in and out of the area.

The Germans used mustard gas for both these purposes in the attacks made against the British in March, 1918. They likewise preceded their attack of March 21, 1918 with a heavy bombardment of mustard gas shells against certain areas in the zone of the attack.

In the Argonne-Meuse attack the Americans used mustard gas to as full an extent as they could get it to protect their right flank, which was dominated by the enemy positions on the right bank of the Meuse river north of Verdun. A greater quantity could have been used in the Argonne-Meuse fight had it been available.

For defensive purposes this gas can be used extensively in projector bombs by gas troops. For purely defensive purposes it could also be used in any kind of cylinder or drum and exploded on the ground to protect an area from enemy attack. Methods similar to this would make the holding of flanking lines during an attack far easier than any other method except by strong fortifications.

HIGH EXPLOSIVE MUSTARD GAS SHELL.

Late in the fall of 1918 the Germans began using mustard gas shell containing a large quantity of high explosive. This shell had considerable destructive effect as a high explosive, besides being a gas shell. This development in the use of mustard gas is an exceedingly important one. Not only is the shell an effective high explosive shell, but it makes mustard gas far more deadly than any other form in which used. The large amount of high explosive scatters the gas widely in the form of minute particles of liquid. These drawn into the lungs produce a far more deadly burn for the reason that the amount of gas that may be breathed into the lungs in the form of minute particles of liquid is enormously greater than any that will be breathed in from ordinary field concentrations of the gas. It should be added that these ordinary field concentrations are probably one in 500,000 to one in 2,000,000 of air.

METHODS OF FIRING MUSTARD GAS.

Mustard gas because of its persistency and effectiveness in low concentrations is used ordinarily to gas large areas. For this purpose accuracy in hitting a given point is not necessary, and hence the increase in the dispersion of shots at longer ranges need not be taken into account as is the case when it is desired to hit a given point. Likewise the number of guns required to cover a given area is small. This for the reason that it is not

necessary to fire in the same locality more than once in 24 hours. The high explosive shell, however, changes this method of firing. Since it is deadly both as a high explosive and as a gas, it can and will be used against small targets. In fact, it will be used exactly as high explosive is used, with the single exception that care must be taken to allow sufficient time for the gas to disperse if one desires to occupy the places bombarded with the gas. However, the persistency is greatly reduced by this wide dispersion of the gas in the form of minute particles, though how much has not been worked out among Americans, and will not be if existing orders are carried out to demobilize the Chemical Warfare Service and stop all researches into poisonous gases. It may be advisable in the future to have two kinds of mustard gas shell, high explosive to be used when immediate casualties without great persistency is desired, and the ordinary mustard gas shell to forbid certain territory to the enemy in which case great persistency is desired.

Americans may be exceedingly glad that the German manufactured comparatively small quantities of this gas and that he was completely out of it when the Argonne fight began. Had he possessed it in the same quantity he possessed high explosive we would probably have had 50,000 to 100,000 more casualties.

Mustard gas was used against the British at Ypres in July, 1917, where chlorine had first been used in cloud attacks more than two years earlier. The casualties from these first two or three mustard gas attacks were very severe for two reasons: first, up to that time all gases used were nearly instant in their effect, that is they were irritant to the eyes, throat and lungs; and second, the odor of the mustard gas was not very powerful and hence no one suspected that gas was being fired. Thus the British simply took shelter from the high explosive, feeling perfectly safe until a few hours had elapsed, when large numbers of men began to get sick and go blind.

NON-PERSISTENT GASES.

Phosgene is the king of non-persistent gases and for an offensive it is at present the best of all gases. It has very low persistency, is highly lethal, fairly quick-acting, easily manufactured and can be put into any kind of shell. It is used to the best advantage in the largest caliber guns that are available in large numbers. In our army there are the 155-millimeter gun and howitzer. A concentration of one part in 2000 is deadly in three minutes, while 1 part in 30,000 or less is deadly in a proportionately greater time. It is also effective but with a rapidly decreasing ratio down to one part in 200,000 after which it may be breathed indefinitely. In fact, in an ordinary attack one part in 50,000 may be considered as not dangerous, as it will be

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dispersed before enough will be breathed to cause any considerable injury.

There are a number of other gases that may be classed in this same group. Chloropicrin, although about three times as persistent and sometimes considered separately, really belongs to the phosgene group.

Of all gases with a comparatively low boiling point, phosgene is the most generally used. It quickly volatilizes, thus making it valuable for cylinders, projectors, Stokes mortars or artillery. On the other hand, the pressure generated by it in warm weather is not too great to permit its use in shells in any climate, in any weather. The gas is about three and one-half times as heavy as air, and while it has some delayed action in the lower concentrations, it is very quickly fatal in high concentrations. For instance, in one projector attack against the Americans there were six deaths in the first five minutes after the attack. These, of course, were men caught without their masks in a very heavy concentration of gas.

On the other hand, as illustrating the delayed action of phosgene, a large scale raid made by one of the American divisions during its training is highly illuminating.

This division decided to make a raid on enemy trenches which were situated on the opposite slope of a hill across a small valley. Up stream from both of the lines of trenches was a French village in the hands of the Germans. When the attack was launched the wind was blowing probably six or seven miles per hour directly down stream from the village, i.e., directly toward the trenches to be attacked. The usual high explosive box barrage was put around the trenches it was intended to capture.

Three hundred Americans made the attack. During the attack a little more than three tons of liquid phosgene was thrown into the village in 75 and 155-millimeter shells. The nearest edge of the village shelled with phosgene was less than 700 yards from the nearest attacking troops. None of the troops noticed the smell of phosgene, although the fumes from high explosive were so bad that a few of the men adjusted their respirators. The attack was made about 3 a.m., the men remaining about 45 minutes in the vicinity of the German trenches. The men then returned to their billets, some five or six kilometers back of the line. Soon after arriving there, that is in the neighborhood of 9 a.m., the men began to drop, and it was soon discovered that they were suffering from gas poisoning. Out of the 300 men making the attack 236 were gassed, four or five of whom died.

The Medical Department was exceedingly prompt and vigorous in the treatment of these cases, which probably accounted for the very low mortality.

This is the most interesting case known to the author

of the delay action that may occur in gassing from phosgene. Here the concentration was slight and there is no doubt its effectiveness was largely due to the severe exercise taken by the men during and after the gassing.

It should be remarked in closing that while gas officers were not consulted in the planing of this attack, a general order was shortly thereafter issued requiring that gas officers be consulted whenever gas was to be used.

EFFECT OF PHOSGENE ON MEN.

Phosgene acts both as a direct poison and as a strong lung irritant, causing rapid filling of the lungs with liquid. The majority of deaths are ascribed to the filling up of the lungs and consequently to the suffocation of the patients through lack of air. This filling up of the lungs is greatly hastened by exercise. Accordingly, all rules for the treatment of patients gassed with phosgene require that they immediately lie down and remain in that position. Thus they are not even allowed to walk to a dressing station. The necessity of absolute quiet for gassed patients undoubtedly partly accounts for the later habit of carrying out a prolonged bombardment after a heavy phosgene gas attack. The high explosive causes confusion, forcing the men to move about more or less and practically prevents the evacuation of the gassed. In the early days of phosgene the death rate was unduly high because of lack of knowledge of this action of the gas. Due to the decreased lung area for oxygenizing the air, a fearful burden is thrown on the heart, and accordingly, those with a heart at all weak are apt to expire suddenly when exercising after being gassed.

METHOD OF FIRING PHOSGENE.

Since phosgene is non-persistent and comparatively high concentrations are required, it is necessary for artillery to fire it as rapidly as possible. For that reason it is usually fired in two to three-minute bursts of rapid fire directly upon the target. As practically all masks protect thoroughly against this gas in nearly all concentrations obtained by shell fire, it is necessary to surprise the enemy without his mask on. If the enemy be not thus surprised the only casualties will be those resulting from defective masks or from confusion which causes the displacement of masks. It is believed, however, that as gas warfare develops phosgene shell will often be fired in small numbers just as high explosive is fired, that is, directly upon trenches, buildings, woods, crossroads, and other points where personnel may be expected.

Unless masks are adjusted beforehand, one phosgene shell will get more casualties than one high explosive shell in all but

extremely rare and special cases. This effect was noticed among the Germans in the battle of the Argonne, where in several instances men were found lying dead with masks in their hands ready to put on. Evidently they were completely overcome by phosgene before they could adjust the mask. This firing of individual phosgene shells from guns of 155-millimeter or larger caliber will increase. It forces the enemy constantly to wear his mask or run the risk of being killed, just as in the case of the Germans alluded to above. Certainly since gas shell are probably less expensive than high explosive shell, they should be used just as freely as high explosive, and undoubtedly they will be in the future.

Phosgene can be used most effectively at night against cross-roads and all other points where it is thought the enemy may congregate or be passing. By dropping sudden bursts of phosgene on these points tremendous confusion is caused and with it a certain number of casualties. This was tried out with very good effect on one or two occasions in the Argonne-Meuse fight. However, the supply of gas shell in that fight was so small as to permit of very little latitude in its use.

But although the total casualties remain about the same, the death rate increases very rapidly with the increase in the caliber of the shell. This is due undoubtedly to the fact that those caught without a mask within say five yards of the bursting of a larger caliber shell will be almost certainly killed. With a small caliber shell, such as the three-inch, the distance at which the gas is deadly is probably only one, or at the most two yards.

PHOSGENE IN PUMICE STONE.

Late in the fall of 1918 the Germans began to use in their projector or 173-millimeter minenwerfer gas attacks a shell filled with phosgene soaked in pumice stone. Apparently enough pumice stone in the shape of small fragments about the size of a pea or less was used to fill the shell. Then the shell was filled with phosgene, which not only filled the voids in the pumice, but was also absorbed by the latter to its full capacity.

The pumice was added with a view to making phosgene more persistent. The phosgene in the voids was vaporized almost immediately upon the burst of the bomb, while that absorbed by the pumice was given off so slowly in the woods and other closed places as to aid very materially in keeping up the concentration. Just what real value this method of using phosgene had was not determined at the time the war closed. It certainly is an ingenious way of increasing the persistency of a non-persistent gas, and it may be found desirable to extend its use to low persistent lachrymators and other gases, as well as to phosgene.

USE OF PHOSGENE IN BARRAGES

Just at the close of the war phosgene was beginning to be used in the distant parts of a barrage when the wind was blowing toward the enemy. This use is being increased and is believed will be of great importance to that side which has the best mask. In fact, as masks develop in efficiency the tendency will be more and more to use gas closer and closer to one's own troops. If the war had gone into 1919 the new American mask, with its great comfort, low resistance and most excellent vision, would have made it so far superior as a fighting mask to any other that Americans could have afforded so to use gas that every fight would have found both sides wearing the mask.

OTHER LOW PERSISTENT GASES.

There are several other low persistent gases now used while others will undoubtedly be developed in the future. Their use, however, will remain much the same as that of phosgene. That is, they will be used in rapid bursts of fire against large targets or in small number at frequent intervals all over the field of battle, in order to take the enemy by surprise and gas him before he can get his mask on. Persistent gases will continue to be used to force continuous wearing of the mask or evacuation of the gassed area. Thus strong points heavily attacked with persistent gases must be early evacuated or a system of complete reliefs of men organized and put into operation. Either eventuality means a heavy military burden on the troops attacked.

IRRITANT AND LACHRYMATORY GASES.

Among irritant gases diphenyl chlorarsine may be taken as the type. This causes severe sneezing and coughing in comparatively low concentrations and severe vomiting in slightly higher concentrations. Its ability to penetrate masks not especially protected by filter pads of some sort, makes it a valuable addition to the other gases in use. Being effective in exceedingly low concentrations it is fairly economical though the small quantity that can be put into a high explosive shell, to a large extent nullifies its economy.

LACHRYMATORY GASES.

Of lachrymatory gases brombenzyl cyanide is one of the best. It is very persistent, being in that respect nearly equal to mustard gas and is effective in extremely low concentrations, one part in 10,000,000 being sufficient to make vision impossible without a mask.

This quick action of lachrymatory gases is one of their prime features when used with mustard gas. If mustard gas be used along fighting may be continued for three to six hours without forcing the enemy to wear his mask. This, of course, exposes him to being gassed but as the death rate from mustard gas in ordinary field concentrations is comparatively low, the enemy will take this chance in a critical situation. On the contrary, if a number of lachrymatory shells are sent over, he will be forced to put on his mask immediately and continue wearing it indefinitely. It must never be forgotten that lachrymators and irritants are essentially economical due to their effectiveness in extremely low concentrations. They are thus valuable to force wearing of the mask when it would be impossible to do that by the use of more deadly gases, owing to the number of the latter that would be required. One good lachrymator shell will force wearing of the mask over an area that would require 500 to 1000 phosgene shells to produce the same effect.

There is no authentic instance of gas ever being dropped from an airplane or balloon though there is no reason for this except fear of reprisals or lack of sufficient gas.

The possible use of gas in airplanes appealed to the Americans at once. In October, 1917, the author, when drawing up the first paper on gas warfare for the American Gas Service, suggested both the proper gases and their tactical uses in airplanes.

In connection with this subject of gases in airplanes there were many rumors during the war that the Germans were preparing a large number of gas bombs and that they actually dropped some. Notwithstanding every such report was investigated, no authentic case was ever found and it is believed the Germans never dropped a single gas bomb within the Allied lines.

Undoubtedly fear of reprisals by the Allies is all that kept the German from dropping gas from aircraft due to both his limited supply of gas and to the growing strength of the Allies in the air. Indeed as early as the fall of 1917, the German became alarmed about the Allied gas progress and tried by appealing to the International Red Cross to stop its use altogether.

That all nations were experimenting with airplane gas bombs and methods of exploding them is certain; and since they can be made such a powerful harassing agent, it is certain they will be used in any big war in the future.

The tactical use of gas in aircraft would be very much the same as for other services. The highly persistent gases as mustard gas would be used against concentration camps, road and railroad crossings, areas, or in woods and villages used to screen movements.

The following chemicals and chemical mixtures were actually employed by the opposing armies at the front. If used by more than one belligerent, the originating army is given first. In addition to these, many other chemical shell fillings were in the

experimental stage and some were being manufactured on a large scale but did not reach the front.

CHEMICAL	BELLIGERENT	EFFECT	MEANS OF PROTECTION
Acrolein (Allylaldehyde)	French	Lachrymatory Lethal	Hand grenades
Arsenic Chloride		(In mixtures. See below)	
Benzyl Iodide	French	Lachrymatory	Artillery shell
Benzyl Chloride	French	Lachrymatory	Artillery shell
Bromacetone	French	Lachrymatory Lethal	Artillery shell
Brombenzylcyanide	French	Lachrymatory	Artillery shell
Brommethylethylketone	German	Lachrymatory Lethal	Artillery shell Artillery shell
Benzyl Bromide	German French	Lachrymatory	Artillery shell
Chlorine	German British French American	Lethal	Cylinders (cloud gas)
Chlorsulphonic Acid	German	Irritant	Hand Grenades, light minenwerfer
Chloracetone	French	Lachrymatory	Artillery shell
Chlorbenzene (as solvent)	German	Lachrymatory	Artillery shell
Chloropicrin	British French German American	Lethal Lachrymatory	Artillery shell Trench mortar bombs Projectors
Cyanogen Bromide	Austrian	Lethal	Artillery shell
Dichlormethylether (as solvent)	Ger.	Lachrymatory	Artillery shell
Diphenylchlorarsine	German	Sternutatory Lethal	Artillery shell
Dichlorethylulphide	German French British American	Vesicant Lethal Irritant	Artillery shell
Ethylchlorarsine	German	Lethal	Artillery shell
Ethylchloracetate	British	Lachrymatory	Artillery shell, 4 in. Stokes mortar, hand grenades.
Hydrocyanic acid	French	(In mixtures. See Below)	
Methylchlorsulphonate	German	Irritant	Minenwerfer
Monochlormethylchlorformate	German French	Lethal Lachrymatory	Artillery shell
Phosgene	British French German American	Lethal	Projectors, trench mortars, artillery shell, cylinders.

CHEMICAL	BELLIGERENT	EFFECT	MEANS OF PROTECTION
Phenylcarby- laminechloride	German	Lachrymatory Irritant	Artillery shell
Trichlormethyl- chlorformate	German	lethal	Artillery shell
Stannic Chloride	British	Irritant	Hand Grenades
	French	Cloud forming	Artillery
	American		Projectors
			4-in. Stokes Mortar bombs
Sulphuric Anhydride	German	Irritant	Hand grenades, minenwerfer, Artillery shell
Xylol Bromide	German	Lachrymatory	Artillery shell
MIXTURES			
Bromacetone(80%)and Chloracetone(20%)	French	Lachrymatory Lethal	Artillery shell
Chlorine (50%) & Phosgene (50%)	British German	Lethal	Cylinders
Chlorine(70%) & Chlorpicrin (30%)	British	Lethal Lachrymatory	Cylinders
Chlorpicrin(65%) & Sulphuretted Hydrogen (35%)	British	Lethal Lachrymatory	Cylinders
Chlorpicrin(80%) & Stannic Chloride(20%)	British French	Lethal Lachrymatory	Artillery shell Trench Mortar bombs
	American	Irritant	Projectors
Chlorpicrin(75%) & Phosgene (25%)	British	Lethal Lachrymatory	Artillery shell Trench mortar bombs ,pro- jectors
Dichlorethyl Sulphide 80% and	German	Vesicant	Artillery shell
Chlorbenzene (20%)	French British American	Lethal	
Ethyl carbazol (50%)	German	Sternutatory	Artillery shell
Diphenylcyanarsine(50%)		Lethal	
Ethyl Dichlorarsine(80%)	Ger.	Lethal	Artillery shell
& Dichlormethylether (20%)		Lachrymatory	
Ethylidoacetate (75%) & Alcohol (25%)	British	Lachrymatory	Artillery shell 4-in. Stokes mortars, hand grenades
Hydrocyanic acid (55%) & Chloroform (25%) & Arsenious Chloride (20%)	British	Lethal	Artillery shell
Hydrocyanic Acid (50%) & Arsenious Chloride (30%)	French	Lethal	Artillery shell
Stannic Chloride (15%) & Chloroform (5%)			

Chemical	BELLIGERENT	EFFECT	MEANS OF PROTECTION
Phosgene (50%) & Arsenious Chloride(50%)	British	Lethal	Artillery shell
Dichlorethyl Sul- phide (80%)	German	Vesicant	Artillery shell
Carbon Tetra- chloride (20%)	French	Lethal	
	British		
	American		
Phosgene (60%) & Stannic Chloride (40)	British	Lethal	Artillery shell
Methyl Sulphate (75%) &	French	Irritant	
Chlormethyl Sulphate (25%)		Lachrymatory	Artillery shell
		Irritant	

Note:- In the mixtures the percentages indicate proportions by weight.

Phosgene and lighter gases could be used at night from bombing planes for producing casualties in camps, billets, rest areas, and similar places. Lachrymatory gases could be used for harassing and for forcing the wearing of the mask. That such use of gas will come in any future war is certain, since its effect as a harassing agent would be entirely too powerful to be overlooked.

An interesting thing to remember in this connection is that if towns are bombed with gas the safest places will be the tops of buildings since cellars which are safe against high explosives are death traps for gas unless the cellars are hermetically sealed, or gas masks worn.

GAS IN HAND GRENADES.

Many attempts have been made to use gas in hand grenades but with very few results that can be said to have been worth the effort. Mustard gas has been used very few times for exploding in enemy dugouts captured during a raid and evacuated immediately thereafter.

Stannic chloride and smokes similar to the irritant or lachrymatory gases have been used to throw into enemy dugouts and thus force the occupants out. It is believed the use of these gas hand grenades in the future will be little if any more than in the past with the possible exception of the rifle grenade.

At best, gas grenades can be said to be minor side issue of chemical warfare. They belong to that class of implements of war that have an excellent occasional use, though the occasions for their use are so rare as to make it a great question whether or not it pays to manufacture, store and handle them.

SUMMARY OF TACTICAL USES OF GAS

Gas Tactics--(General)

With the rapid increase in the use of gases in war, it is important that all officers, but particularly staff officers, should take up the study of the tactical use of gases in phases of war. Gas can never be used properly and to the extent that it should be until staff officers have learned to consider it in all problems of attack and defense.

USES OF MUSTARD GAS BY ARTILLERY.

(a) Mustard gas is of the greatest importance to the artillery due to its great persistency and effectiveness in very low concentrations. It can be used everywhere along the front in large quantities with safety 3000 yards or more from the front line, no matter in what direction the wind is blowing, provided its use is discontinued from three to five days prior to the attack in those places to be crossed by attacking troops during the first day. Its persistency is such that if three days be not allowed to elapse there may be sufficient gas to force our own troops to wear masks or be gassed. When mustard gas has been thus used it can be followed up with low persistency lethal and lachrymatory gases to fill in the interval between the time mustard gas has been stopped and the time of the attack, for the purpose of forcing the enemy always to wear masks, as well as to produce casualties during that period.

(b) It can be used on strong points, such as villages, small groves, valleys, and similar places in the zone of attack if it is not intended to attack them directly. The firing of mustard gas can be kept up on these places even during the attack, thereby forcing the enemy to wear masks and otherwise protect himself continuously or evacuate the places. In any event, the harassing value of the gas will more than pay for its expenditure by its wear on the troops and by interfering with their fighting efficiency while the attack is being pushed at other points. A number of such instances occurred in the great offensives in Flanders, and Picardy in 1918. If this firing of mustard gas can be kept up for a week or ten days the enemy will have only two alternatives, a continuous succession of reliefs wearing masks or evacuation of the area.

(c) Mustard gas can be used continuously on any area, open or otherwise within the zone of the attack but which will not be crossed during the advance. In such cases, in order that the areas may not be too prominent, other gases can be used on the parts of the front to be attacked. If some of the other gases be mixed with the mustard gas, the smell of the latter will be more or less disguised, and the enemy will be unable to tell what areas are left free of mustard gas and thus where the attack will be made.

(d) Mustard gas can be used on reserves, lines of communication, concentration points, villages, etc., in the line of advance, provided that they are far enough back of the enemy's front to be sure that the place will not be reached for at least three days after the firing of the mustard gas has ceased. The terrific harassing value of mustard gas must never be lost sight of and this alone is worth its use to the fullest extent obtainable. It should, however, be accompanied with more or less high explosive and other gases, including lachrymators, in order that the enemy may have to use all precautions and not those applicable to mustard gas alone.

USES ON THE DEFENSIVE.

On the defensive mustard gas can be used in large quantities in the same way as on the offensive against reserves, lines of communication, villages, and all enemy concentrations at all times where the distance is more than 3000 yards back of the front line. By reducing the quantity gradually to one pound every ten yards it can be fired every six hours any time down to within 500 yards of our own lines. If a withdrawal is contemplated, it may be fired in large quantities to within 500 yards of our line if the wind be blowing toward the enemy, providing, of course, the withdrawal will occur within a few hours and to a distance not less than 2500 yards from our front line. If the withdrawal is to continue to greater distances, the fire of mustard gas can be kept up in the same way at all times during the withdrawal thereby forcing the enemy to wear masks or be gassed over the whole area he must cross for two to seven days after the firing has ceased, the time depending upon the weather and the terrain.

The uses of mustard gas on stabilized fronts are practically the same as on the defensive, except that particular attention should be paid to battery positions, as well as to enemy concentrations, lines of communication, cross roads, villages, dugouts, rest areas and billets. Its use should be frequently accompanied by high explosive and also be preceded, where sufficient highly lethal gases are available, by two-minute bombardments with the latter gases to produce casualties by surprise. Irritating and lachrymatory gases should be used also to make the wearing of the respirator continuous or difficult or both. The lethal gases may be used with effect in two-minute bursts of fire at three-to eight-hour intervals on selected targets during an extended mustard gas bombardment to catch careless or weary troops who may take a chance and remove the mask.

USE OF LOW-PERSISTENT GASES, AS PHOSGENE.

Due to their comparatively slight persistency, there are no clearly defined lines between their use on offense and defense. The

highly lethal gases, with the exception of chloropicrin, will persist in the open with a four-mile wind for only one to three minutes, making it safe to cross such areas under those circumstances in a few moments after the bombardment ceases. If the gases be used in thick woods, the time that should elapse before it is safe without a mask will be at least three hours and in villages, trenches and similar places from two to three hours. If chloropicrin be used, all of these times will have to be doubled. It should be remembered, that the vapor of poisonous gases is generally about three times as heavy as air and will thus roll into and remain in deep trenches and similar places for two to six hours in fairly high concentration. Such places must be avoided, or else entered by persons with masks on. These gases when used in artillery, are best employed in bursts of fire, particularly at night, to produce casualties by surprise, through slowness of adjustment of masks and confusion.

LACHRYMATORY AND IRRITATING GASES.

These are useful to save mustard gas and the highly lethal gases through forcing the wearing of the mask to protect the eyes from the lachrymator and the nose, throat and lungs from the irritating gases. The value of these gases arises from the fact that their irritating effect on the eyes or respiratory organs is instantaneous and one shell is as good to force the wearing of the mask as 500 to 1000 lethal gas shells. It should be noted that mustard gas is effective in low concentrations, being in that regard almost equal to the lachrymatory gases. However, it has a delayed action of four to twelve hours and hence is not available if it is desired immediately to force the wearing of the mask. Furthermore, it cannot be used, as previously stated, in areas that it is proposed to occupy, unless its use is stopped three to eight days beforehand. The lachrymatory and irritating gases are thus a valuable means of bridging over the period between stopping the firing of mustard gas and the advance, remembering always that many lachrymatory gases are very persistent.

USE OF GAS BY GAS TROOPS.

Although the present tendency of gas warfare indicates that the future will see possibly 70 per cent of all gas fired from artillery shell, there is still a great field of usefulness for gas troops. Cloud gas is not obsolete. Due to the very high concentrations obtained by gas clouds and to their corrosive effects on machine guns and small arms as well as on ammunition in general, it is one of the most dreaded forms of gas attack.

PROJECTOR AND STOKES MORTAR ATTACKS

The modern projector with its eight-inch bombs and 30 pounds of liquid gas when fired simultaneously in groups of several hundred to several thousand against dugouts, villages, strong points and other places, is a very effective means of using highly lethal gases. It has the advantage over a cloud attack that much less attention must be paid to the direction and force of the wind. It also affords a means of dropping a heavy concentration of gas onto a distant point in a very short interval of time. The firing of these projectors combined with the firing of other gas and high explosive shell later by the artillery, gives promise of being an efficient method of obtaining casualties.

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GAS IN DEFENSE.

INTRODUCTORY.

The best defense against any implement of war is a vigorous offense with the same implement. This is a military axiom that cannot be too often, or too greatly emphasized, though like other axioms it cannot be applied too literally. It needs a proper interpretation - the interpretation varying with time and circumstances. Otherwise serious disaster may result. Thus in gas warfare a vigorous offense with gas is the best defense against gas. This does not mean that the enemy's gas can be ignored. Indeed, it is more important to make use of all defensive measures against gas than it is against any other form of attack. Gas being heavier than air, rolls along the ground, filling dugouts, trenches, woods and valleys - just the places that are safest from bullets and high explosives. There it remains for hours after it has blown away in the open, and, since the very air itself is poisoned, it is necessary not only that protection be general but that it be continuous during the whole time the gas is present.

EARLIEST PROTECTIVE APPLIANCES.

The earliest protection against gas was the crudest sort of a mask. The first gas used was chlorine and since thousands of people in civil life were used to handling it, many British knew that certain solutions, as hypo-sulphite of soda, would readily destroy it. They also knew that if the breath could be drawn through material saturated with those solutions, the chlorine would be destroyed. Thus it was that the first masks were simple cotton, or cotton waste pads, which were dipped into hypo-sulphite of soda solutions and applied to the mouth and nose during a gas attack. These pads were awkward, unsanitary, and, due to the long intervals between gas attacks, were frequently lost, while the solution itself was often spilled or evaporated. The net result of all this was poor protection and disgust with the so-called masks.

DESIGN OF NEW MASKS.

After using these, or similar poor excuses for a mask, for a few weeks, the British designed what was known as the P.H. helmet. This was simply a double sack of flannel, saturated with oils and chemicals that would destroy chlorine. It was fitted with two celluloid eye pieces and, at a somewhat later date, with an expiratory valve. In a gas attack the sack was pulled over the head and tucked under the blouse around the neck, the gas tight fit being obtained by buttoning the blouse over the ends of the sack. This P.H. helmet was quite successful against chlorine and, to a much lesser extent, against phosgene, a new gas introduced during the spring of 1916.

However it was warm and stuffy in summer - the very time when gas is used to the greatest extent - while the chemicals in the cloth irritated the face and eyes, especially when combined with some of the poisonous gases.

Probably as a result of experience with oxygen apparatus in mine rescue work, some Englishman suggested making a mask of which the principal part was a box filled with chemicals and carried on the chest. A flexible tube connected the box with a mouth-piece of rubber. Breathing was thus through the mouth and in order to insure that no air would be breathed in through the nose, a nose clip was added.

This, of course, cared for the lungs, but did not protect the eyes. Their protection was secured by making a face-piece of rubberized cloth with elastics to hold it tight against the face. The efficiency of this mask depends, then, first upon the ability of the face-piece to keep out lachrymatory gases which effect the eyes, and, second upon a proper combination of chemicals in the box, to purify the air drawn into the lungs, through the mouth-piece. It is not considered necessary or desirable here to go into the details of construction of the mask. Accordingly only the salient points will be touched upon.

CANISTER OR RESPIRATOR BOX FILLINGS.

The materials of the box, or canister as it early became called, are charcoal, and soda lime and cement granules moistened with a permanganate solution. The soda lime granules and permanganate absorb and destroy the gases directly, while the charcoal first absorbs them and later, absorbing oxygen, allows the latter to destroy the gases by oxidation. As time went on tremendous improvements were made in the quality of the charcoal, so that towards the end of the war it was felt that the best grades of charcoal might alone be sufficient. It is interesting to note that the best charcoal is made from hard nuts and the pits of certain fruits, such as the peach. But even with these nuts and pits the proper heat treatment of charcoal is of the highest importance. To get maximum efficiency the charcoal must be so heated as to obtain maximum porosity by abstracting all oils and tars.

The story of gas mask charcoal production in the United States is an extremely interesting one. Starting with the knowledge gained in making charcoal for ordinary purposes, the work of manufacture was developed until at the end of the war charcoal was being produced on an enormous scale by methods totally different, but far simpler, cheaper, and more efficient than in the early days.

OBTAINING CHARCOAL MATERIAL.

When after a year of war it was fully realized that the protection of troops against gas depended largely on charcoal and that charcoal from hard nuts and fruit pits was best, a campaign was started in the United States to collect these fruit pits.

People not familiar with the temper of the Americans ridiculed the idea that enthusiasm could be aroused for the saving of peach pits, stating that efforts to do so would simply make the War Department ridiculous. The Chemical Warfare Service, however, did not believe this and hence launched, through the Red Cross and other agencies, a public campaign for the saving and storing of peach and apricot pits. As to the success of the campaign, suffice it to say that ten thousand tons were collected in California alone. In order to reduce transportation these peach pits at points distant from the mask factory in Long Island City, were made into crude charcoal in gas furnaces near at hand. This reduced the volume and weight to be shipped by about 70%. When it is considered that not less than 20 tons of finished charcoal per day was required and that the weight of the final product is only about 5% of the weight of the peach pits used, one can readily realize what a huge business it was to just supply the daily 400 tons of materials for charcoal alone in masks.

PROTECTION AGAINST SNEEZING GAS.

While the charcoal and soda lime granules furnished an adequate protection against all known true gases, they did not furnish protection against certain smokes or against minute particles of liquid gas. Since certain smokes, as stannic chloride, though not deadly are so highly irritating as to make life unbearable, it early became necessary to devise means for keeping them from going through the masks. This was done in the first masks by adding a sufficient thickness of cotton batting. The cotton was usually placed in three layers alternating with the charcoal and granules, as it was thought the latter would be held in place better by that means.

Sometime after stannic chloride came into use the Germans started firing shells containing a small quantity of diphenylchlorarsine, popularly known as "Sneezing Gas". This is not a true gas but a solid and as the solid material reacted unfavorably upon the high explosive it was necessary to separate the two by placing the diphenylchlorarsine in bottles. The sizes of these bottles for each caliber of shell were such that they would permit of about a half inch of high explosive all around the bottle and about two inches both above and below the ends.

This diphenylchlorarsine is an exceedingly powerful irritant. It causes an intense burning sensation and ache in the nose and temples and a burning sensation in the throat and lungs. It is very seldom fatal, however, since the concentration obtainable from shell fire in the field is high enough to cause death only on extremely rare occasions. It does, however, cause such severe coughing and sneezing, with vomiting in the higher concentration, that it occasionally causes the removal of the mask, thus permitting the gassing of the victim by poisonous gases sent over for that purpose. This last result was probably the main object of the German in beginning the use of diphenylchlorarsine. He undoubtedly continued its use because he knew that it penetrated the first masks even

when fitted with sufficient cotton batting to keep out stannic chloride, and, while it might not kill, still it might seriously affect the morale of troops. The effect lasts only a very few hours, usually two to four, but the German reasoned that even that length of time would probably pay for the ammunition expended through disorganizing troops standing ready to repel an attack.

CHOICE OF MASKS FOR U. S. TROOPS.

When it became necessary with the creation of a Chemical Warfare Service in France in August, 1917, to decide upon a mask for American troops, there were available for purchase two types - the British type referred to above and the French M2. The French M2 consisted essentially of 32 layers of cloth impregnated with various chemicals and oils through which the air was breathed both in and out. The chemicals and oils were chosen for their ability to absorb and destroy gases. The mask was of course fitted with eye-pieces and elastics to go around the head in order to bind the face-piece firmly to the face and thus get gas tightness, even under the pressure of breathing. This mask was quite effective against ordinary field concentrations of most gases, but was utterly inadequate to care for the high concentration of phosgene obtained in the front line from cloud gas or from projector gas attacks. It was also poor against chlorpicrin. The M2 was, however, very light and easy to carry and moreover was deemed sufficient to protect against concentrations of cloud gas even, at points more than five miles distant from the front line.

Furthermore, it was felt desirable at first to have an auxiliary or emergency mask in addition to the principal one, for use in case the principal mask was worn out or damaged. Accordingly both types of masks were adopted and the day after the writer took charge of the Chemical Warfare Service on August 22, 1917, 100,000 of each were purchased, although there were then only ten or twelve thousand American troops in France requiring masks. Later additional masks of both kinds were purchased to tide over the American troops until a sufficient quantity of the British type masks could be manufactured in the United States. The total of British masks purchased amounted to about 700,000.

However, within a comparatively short time after American troops got into the front line it was realized that a second mask inferior in protection to the first was highly undesirable. During a gas attack men seemed to acquire an uncontrollable desire to shift from one mask to the other. This shifting in nearly every case resulted in a casualty. We then came rapidly to the conclusion that one mask only should be furnished, and that one the best that could be made, and then to impress upon the soldier the fact that his life depended upon the care he took of his mask. This proved to be an entirely sound conclusion as the number of men gassed through

injuries to the mask was comparatively small. An interesting proof of the value the soldier placed upon his mask was shown by the articles of equipment thrown away by 10,000 British stragglers in the great German offensive of March, 1918. Of the articles thus thrown away the gas mask came at the foot of the list, with only 800 missing. The steel helmet is said to have come next with about 4,000 missing.

SIZES OF FACES FOR MASKS.

When adopting the British respirator in August, 1917, it was decided that the American face as well as the American stature was probably larger than the English. Accordingly inquiry was made in regard to the sizes of masks issued to the Canadians as it was thought probably they required a greater proportion of the larger size masks than did the English. When prescribing the relative quantities of each size of mask to be furnished Americans, the Canadian requirements were taken as a base but with the larger sizes increased slightly over the Canadian requirements. As a matter of fact even these increases proved considerably too small so that the numbers in the two sizes above normal had to be finally more than doubled.

GERMAN AND FRENCH A. R. S. MASK.

The German very early, perhaps even before the war, had invented a mask utilizing the principle of the British mask, with a box containing chemicals and charcoal, to breath through. Instead, however, of carrying this box in a separate compartment on the chest, he attached it directly to the face-piece in front of the mouth. This mask is a simple one, fairly light and fairly efficient. It has neither outlet nor inlet valve, the air being both inspired and expired directly through the chemicals and charcoal. The French thought so highly of this type of mask that in the summer of 1917 they began experiments and finally perfected one made on the same general principle, except that they added an expiratory valve to avoid forcing the air out through the Chemicals. This was to increase the life of the Chemicals and to decrease the rise in the resistance of the box during long wear, due to moisture accumulating in the chemicals and charcoal.

TISSOT MASK.

It should be stated that another was early invented by a Frenchman named Tissot and that this mask was more comfortable and on the whole gave better protection than any other. It had a separate box for chemicals carried on the back and as it omitted the mouth-piece and nose-clip, provided for natural breathing. It is also arranged so as to bring the dry inspired air over the eye-pieces, to sweep off any moisture that collects there. It thus keeps the

eye-pieces clear under nearly all conditions of use. This clearness of vision was a tremendous improvement over anything then in existence and was so highly desirable that work was at once started in the American Gas Service in France to design a mask suitable for field conditions, but embodying this principle. The Tissot mask had a pure rubber face-piece, with a large cumbersome box, and no suitable carrying case. It was thus too frail, too clumsy, and too heavy for general issue to troops in the lines. The rubber was easily torn, while the box added too much weight to the soldier's load. However, it was issued by the French and Americans to large numbers of special observers in lookout stations, and to artillerymen and others who had time to adjust the mask properly and to take suitable care of it.

OBJECTIONS TO GERMAN TYPE MASK.

The American Gas Service felt from the beginning that a design which attached the box of chemicals to the face-piece was unsound in principle, since it did not allow proper flexibility for increasing the size of the box to care for new gases. Furthermore, the weight of the box during movement caused the face-piece to swing slightly from side to side. This interfered with vision and tended to lift the face-piece away from the face and allow gas to enter. That the objections of the American Gas Service to this type were correct was proved by the difficulty encountered toward the end of the war by both the French and the Germans in trying to provide a suitable filter for protection against particulate clouds and the smokes, such as stannic chloride and diphenylchlorarsine.

STRUGGLE BETWEEN MASK AND GAS.

As between the mask and poisonous gases, we have the old struggle of the battleship armor against the armor-piercing projectile. While the armor-piercing projectile has always had a little the best of the game, it is just the reverse with gases. The gas mask has always been just a little better than the gases, so that very few casualties have occurred through failure of the mask itself. This margin of safety has never been any too great, and that we have had a margin at all is due to the energy, skill and enthusiasm of those developing and manufacturing masks in England, France, and particularly in the United States.

However, the mask at the best is uncomfortable, causes some loss of vigor, and even with the very best American masks there is some loss in vision. The wearing effect on troops results mostly from the increased resistance in breathing. Accordingly a tremendous amount of study and effort was made to decrease this breathing resistance. In the English type masks this resistance was equal to the vacuum required to raise a column of water about four and one-half inches. Adding the sulphite paper to protect against diphenylchlorarsine increased this resistance by about one inch. This put

a heavy burden on the wearer of the mask whenever it was necessary for him to do any manual labor while wearing it. In addition earlier masks left a good deal to be desired in the way of reducing resistance by proper sized tubes, angles and valves through which the air was drawn. This was much more easily overcome than reducing the resistance through the chemicals and charcoal and the materials for protection against diphenylchlorarsine. In the latest type canister, devised after long trials for the American forces, this resistance was brought down to about two inches of water. What this reduction in resistance means no one knows except one who has worn the old mask with its mouth-piece and four to six inches' resistance and has then replaced that mask for one through which he breaths naturally with only two inches' resistance.

DESIGN OF NEW AMERICAN MASK.

The American Gas Service felt from the beginning that the mouth-piece and nose-clip must be abandoned and bent every effort toward getting a mask perfected for that purpose. The English opposed this view fiercely for nearly a year. This position on the part of the English was more or less natural. They developed their mask in the beginning for protection against cloud gas. In those days the opposing trenches were close together. Moreover, front line trenches were quite strongly manned. The result was that a large number of men were exposed to a very high concentration of gas, but - and highly important - for a short period only. Inasmuch as the German feared this cloud gas even more than the English there was no danger of his attacking in it. The English rules of conduct during a gas attack called for all movement to stop and for every man to stand ready until the cloud passed. Accordingly, the man was breathing the easiest possible and hence did not suffer particularly from the resistance.

MUSTARD GAS.

With the advent of mustard gas, however, the whole general scheme of protection changed. Mustard gas, as is well known, is effective in extremely low concentrations and has very great persistency. In dry warm weather mustard gas scattered on the ground and shrubbery will not be fully evaporated for two to three days and accordingly will give off vapors that not only burn the lungs and eyes but the soft moist parts of the skin as well. In cool, damp weather the gas remains in dangerous quantity for a week and occasionally longer. Since this gas, in liquid form, evaporates too slowly for use in gas clouds, it is used altogether in bombs and shells. Accordingly it could be expected to be and actually is fired at all ranges from the front line to nearly eight miles back of that line. Hence, with the coming of mustard gas, the need for protection changed from high protection for a short period to moderate protection for very long periods. Indeed, mustard gas makes it necessary for

men to wear masks just as long as they remain in an area infected with it. There is still occasional need for high protection for short periods, but with the increase in the efficiency of charcoal alone it is found that the amount of charcoal and chemicals in the canister can be very greatly reduced and still maintain sufficient protection for the high concentrations encountered in cloud gas and projector attacks.

EXHAUSTION AND MALINGERING.

It seems physically impossible for the ordinary man to wear the British mask with its mouth-piece and nose-clip more than six to eight hours and vast numbers are unable to even do that. How many thousand of casualties were suffered through men losing their mental balance from exhaustion and the discomfort of the mouth-piece and nose-clip no one knows. Such men tore off the mask, stating that they would rather die than endure the torture of wearing it longer. Furthermore, the poor vision of this mask led to the habit of taking the face-piece off while still leaving the mouth-piece and nose-clip in place. This gave protection to the lungs, but exposed the eyes, and as mustard gas affects the eyes very readily this alone led to thousands of casualties. There was another interesting side to this situation. The malingerer who wanted to get out of the front line and was willing to take any action, however cowardly, to achieve that end, deliberately removed the face-piece and thus suffered gassing of the eyes. The effect of mustard gas soon became so well known that the malingerer knew gassing of the eyes never resulted in death or permanent loss of sight. With the new type of American mask, the protection of eyes and lungs depends solely upon the fit around the face and no such playing with the mask can be done.

Without going into further details in regard to masks it is sufficient to state that at the end the Americans had produced a mask thoroughly comfortable, giving complete protection against gases and smoke clouds, and one that was easy to manufacture on the huge scale (fifty to seventy-five thousand per day) which was necessary to provide masks for an Army of three to four million men in the field.

PROTECTION IN WAR IS RELATIVE ONLY.

Napoleon is credited with saying "In order to make an omelet, it is necessary to break some eggs". Every student of war realizes that casualties cannot be avoided in battle and yet one American Staff Officer went so far as to refuse to use gas offensively unless the Chemical Warfare Service could absolutely guarantee that not a single American casualty could occur under any circumstances. This same idea early got into the heads of the laboratory workers on masks. They seemed to feel that if a single gas casualty occurred through failure of the mask, their work would be a failure or at least they would be open to severe criticism. Accordingly efforts were made to perfect masks and to perfect protection regardless of

the discomfort imposed upon the wearer of the mask. This idea was very difficult to eradicate. The laboratory worker who accustoms himself to experiment with a particular thing forgets that he develops an ability to endure discomfort, that is not possible of attainment by the ordinary man in the time available for his training.

Furthermore, if the need for such training can be avoided it is of course highly desirable. This applies to the mouth-piece of the British respirator; to elastics that cause undue discomfort to the face; to the nose-clip and to the large boxes that cause too great resistance to breathing.

It may be taken as a general rule that when protection requires so much effort or becomes so much of a burden that the average man cannot or will not endure it, it is high time to find out what the average man will stand and then provide it even if some casualties result. Protection in battle is always relative. A man who cannot balance protection against legitimate risk has no business passing on arms, equipment or tactics to be used in battle.

TRAINING.

Bitter experience taught the Allies as well as the Americans that no matter how efficient the gas mask and other defensive appliances, they would not take the place of thorough and constant training. One of the greatest difficulties at first was to get American troops to realize that a thing as invisible as gas, with in many cases no offensive smell and producing no immediate discomfort, could be deadly. Nothing but constant drill and constant reiteration of these dangers could get this fact impressed on them. Indeed it never was impressed sufficiently in any of the earlier divisions of American troops in the line to prevent their taking such chances that each division suffered heavy loss on one or more occasions from gas attacks.

A great deal of emphasis had been placed by the English upon the adjustment of the mask in the shortest possible time, this time having been officially set at six seconds after the alarm. The Americans in adopting the mask in toto naturally had to adopt the rules for adjusting it and wearing it. Experiences, however, taught us in a few months that the effort to attain too great speed was dangerous. It tended to rattle the soldier and to result in poor adjustment of the mask, both of which led to casualties. Accordingly in our latest instructions for defense against gas all reference to six seconds was eliminated and emphasis placed on the necessity of accurate adjustment of the mask. Inasmuch as any man, practically without effort or previous drill, can hold his breath for twenty seconds, the need for great speed in adjusting the mask is not apparent.

PSYCHOLOGY IN TRAINING.

While the importance of impressing upon the soldier the danger of gas was early appreciated it was deemed necessary not to make him unduly afraid of the gas. However, as gas defense training in our Army got a big start over gas offense training, this became a matter of very great importance. In fact, due to a variety of causes, training in the offensive use of gas was not available for any troops until after their arrival in France. This resulted in officers and men looking upon the gas game, so far as they were individually concerned, as one of defense only. Accordingly after their arrival in France it became very difficult not only to get some of our officers to take up the offensive use of gas but even to get them to permit its use along the front they commanded.

Notwithstanding all the care taken in training Americans in gas defense there arose an undue fear of the gas that had to be overcome in order to get our troops to attack close enough to their own gas to make it effective. This applied to the use of gas by artillery as well as to its use by gas troops. However, it should be said that in every instance where gas was once used on an American front all officers in the Division, or other unit, affected by it were always thereafter strongly in favor of it.

GERMAN PROBLEMS IN GAS TRAINING.

The Germans also had serious troubles of their own over the psychology of gas training. As stated elsewhere they were using mustard gas nearly eleven months before the Allies began using it. During that time, for purpose of morale, if not sheer boastfulness, the Germans told their men that mustard gas could not be made by the Allies; that it was by far the worst thing the war had produced - and in that statement they were correct - and that they would win the war with it - in which statement they were far from correct. When the Allies began sending it back to them they had to reverse their teachings and tell their men that mustard gas was no worse than anything else, that they needn't be afraid of it and that their masks and other protective appliances gave full protection against it. They thus had a problem in psychology which they never succeeded in fully solving. Indeed there is no question but that the growing fear of gas in the minds of the German is one of the reasons that prompted him to his early capitulation.

HOLDING THE BREATH.

The first regulations and those in general use up to near the close of hostilities, prescribed that the soldier should hold his breath and adjust his mask. It seemed impossible to overcome the natural inference that 'holding the breath' meant first the drawing of a full breath. This was obviously highly dangerous if

gas were actually present before the alarm was heard, as was often the case with projector and artillery gas shell attacks. The change was then made to the phrase "Stop Breathing and Stay Stopped until the Mask is Carefully and Accurately Adjusted".

GAS AT NIGHT.

In the early days it was very difficult to get officers to realize the absolute necessity of night drill in the adjustment of the mask. For various reasons, including surprise, gas attacks were probably eighty to ninety per cent of the time carried out at night. Under such conditions confusion in the adjustment of the mask is inevitable without a great deal of practice before hand, especially for duty in trenches with narrow spaces and sharp projecting corners. There are numerous instances of men waking up and getting excited, who not only gassed themselves, but in their mad efforts to find their masks, or to escape from the gas, knocked others down, disarranging their masks and causing the gassing of from one to three or four additional men. The confusion inherent in any gas attack was heightened in the latter stages of the war by heavy shrapnel and high explosive barrages that accompanied nearly all projector and cloud gas attacks. This shrapnel and high explosive barrage was put down for that very purpose and was continued for three or four hours to cause exhaustion and removal of the mask and to prevent getting the gassed patients out of the gassed area.

DETECTION OF GASES.

Efforts were made by the enemy and by all the Allies throughout the war to invent a mechanical detector that would show when gas was present in dangerous quantities. While scores, perhaps hundreds, of these were invented none proved simple, quick, or certain enough in action to make their adoption desirable. In every case it was necessary to rely on the sense of smell. Thus it was that as the war wore on, more and more attention was given to training officers and non-commissioned officers to detect various kinds of gases in dangerous quantities by the sense of smell.

In the American Gas Defense School for officers this was done wholly by using captured German gases. This was because certain gases have quite different smells, depending upon the impurities in the gas and also upon the solvents sometimes mixed with them. Thus the German mustard gas has a mustard smell, while the Allied mustard gas, due to a slight difference in the method of manufacture, has a very perfect garlic odor. Not only must officers and men who handle gas training know the smell of the various gases, but they must know when the concentration of each is high enough to be dangerous. This is not easy to learn because the strength of the various gases in dangerous concentrations varies through wide limits. Not only does the strength of the gases vary and the sharpness of the odors accordingly, but the mingling of poisonous gases with other gases from

high explosive and shrapnel tends to obscure these odors and make them more difficult of detection.

DECEPTIVE GASES.

A great deal of thought was given toward the end of the war to the subject of deceptive gases which could by powerful or peculiar odors mask the dangerous gases. This masking was to deceive the enemy when dangerous gases were present or to admit an attack without masks while the enemy was wearing his through thinking there was a dangerous gas when as a matter of fact none existed.

In gas warfare, the German, as well as the Allies, was exercising his ingenuity in devising new and startling methods of making gas attacks. A well known trick with the German was to fire gases for several days, particularly against green troops, in concentrations so slight as to do no harm. When he felt that he had lulled those troops to a sense of the ineffectiveness of his gas, he sent over a deadly concentration. In spite of the warning that this was what was happening, he often achieved too great a success. Before the war closed, however, the American was beginning to out-think and out-wit the German in this method of warfare.

MUSTARD GAS BURNS.

With the advent of mustard gas which burned the body, a new and serious difficulty in protection arose. At first it was thought mustard gas burned only when the liquid from the bursting shell actually splashed on the clothing or skin. This was unfortunately soon found to be not true. The gas itself rapidly penetrates clothing and burns the skin even when the concentration of the gas is very low. Probably the majority of burns from mustard gas arose from concentrations of gas consisting of less than one part of gas to five hundred thousand of air. Furthermore, the gas is fully fifty per cent. cumulative in its effects, that is, in extremely low concentrations over a period of hours it will produce more than fifty per cent. the effect that a far higher concentration would produce in a relatively shorter time.

The Allies were not long in discovering that oilcloth, such as is used in many places throughout the United States on camp and kitchen tables, afforded very complete protection against mustard gas. This ordinary oil cloth, however, was too thick, too hot and too heavy for general use. Experiments soon showed that cloth thoroughly impregnated with boiled linseed oil would give protection. In order to make this protection more perfect a certain amount of paraffin was added. All this made the clothing air-tight, rather stiff and always uncomfortable. Notwithstanding these discomforts, hundreds of thousands of oiled suits, and hundreds of thousands of pairs of oiled gloves were made and issued to artillery troops, and to troops especially charged with handling mustard gas shells, or to those employed in destroying mustard gas in shell holes by spreading chloride of lime over them.

The importance of protection against mustard gas burns led to extensive researches being made with a view to finding a cloth which would be comfortable and porous and while stopping mustard gas would yet be sufficiently durable and comfortable to be issued to infantry troops as well as to artillery and other special troops. This, it is understood, had been achieved, just prior to the Armistice. Still more desirable would be the discovery of a chemical substance which could be applied to all uniforms and Army clothing and thus protect the regulation clothing against the penetration of mustard gas, and thereby avoid carrying extra clothing for that special purpose.

PROTECTING TROOPS BY MOVING THEM FROM INFECTED AREAS.

As soon as it was fully realized that mustard gas persisted for several days it was decided to run complete reliefs of men into and out of areas that had been heavily shelled with mustard gas, or better still, where practicable, to completely evacuate the area. Inasmuch as the gas is dangerous to friend and foe alike this method was comparatively safe and was used to a very considerable extent. With the warfare of movement that existed over most of the active front throughout the season of 1918, this moving of troops out of infected areas became highly important and when skillfully done often resulted in a great saving of troops and at the same time prevented the enemy receiving any particular tactical advantage from his mustard gas attacks.

There was one very excellent example of this a few miles to the northwest of Chateau Thierry prior to the counter-offensive of July 18, 1918. At that time the Germans heavily shelled with mustard gas four or five small woods and two or three villages. It was necessary for the men to stay in these woods during the day, as they afforded the only protection obtainable from machine guns, shrapnel and high explosive. At the time this occurred American gas officers generally understood the necessity for getting troops out of a mustard gas infected area. Accordingly all began searching for places safe from the mustard gas. In one particular instance the gas officer of a regiment discovered that a portion of the woods his men were in was free from the gas, and the regimental commander promptly following his advice moved his troops into the free area. As a result of this prompt action the regiment had only four light gas casualties, although all told there were several hundred mustard gas casualties in this attack, the number per thousand generally being from ten to twenty times that of the thousand men just mentioned.

MIXING POISONOUS GASES.

On this as well as other occasions the Germans fired some dipphosgene and Blue Cross (Sneezing gas), as well as mustard gas, This added to the difficulty of determining areas free from the

latter. In the future such mixing of poisonous gases may always be expected and, in addition, gases which have no value other than that of masking the poisonous ones fired. While with practically all gases except mustard gas a man is comparatively safe while breathing a concentration very noticable to the sense of smell, the only safe rule with mustard gas is to consider as dangerous any concentration that can be smelled.

For the reason that this gas persists longer in shaded areas, woods are always to be avoided, where practicable, and also since all gases being heavier than air tend to roll into depressions and valleys, they should also be avoided. There have been a number of authentic cases where batteries in hollows or valleys suffered severely from mustard gas, while troops on nearby knolls or ridges were comparatively free, though the difference in the amount of shelling of the two places was not noticable.

Of great importance with all gases is the posting of a sufficient number of sentries around men sleeping within the range of gas shell. The worst projector gas attack against the Americans was one where the projectors were landed among a group of dugouts containing men asleep without sentries. The result was a very heavy casualty list, coupled with a high death rate, the men being gassed in their sleep before they were awakened.

DESTRUCTION OF MUSTARD GAS.

Prior to the introduction of mustard gas all that was necessary to get rid of gas was to thoroughly ventilate the spot. Thus in trenches and dugouts, fires were found to be very efficient, simply because they produced a circulation of air. In the early days, among the British, the Ayrton fan, a sort of canvas scoop, was used to throw the gas out of the trenches. While this was taken up in the American Service, it did not become very important, since it was found that under ordinary atmospheric conditions natural ventilation soon carried the gas out of the trench proper, while fires in dugouts were far more efficient than the fans. Likewise the Ayrton fan smacked too much of trench warfare which had reached a condition of "stalemate", - a condition that never appealed to the Americans and a condition that it is hoped never will.

With mustard gas, however, conditions were entirely changed, This liquid having a very high boiling point and evaporating very slowly, remains for days in the earth and on vegetation and other material sprinkled with it. This was particularly true in shell holes where the force of the explosion drove the gas into the earth around the broken edges of the hole. While many substances were experimented with, that which proved best and most practical under all conditions, was chloride of lime. This was used to sprinkle in shell holes, on floors of dugouts and any other places where the liquid might be splashed from bursting shells. It was also found very desirable to have a small box of this at the entrance to each dugout, so that a person who had been exposed to mustard gas could

thoroughly coat his shoes with it and thus kill the mustard gas that collected in the mud on the bottom and sides of his shoes.

CARRYING MUSTARD GAS ON CLOTHING.

There are many instances where the occupants of dugouts were gassed from the gas on the shoes and clothing of men entering the dugout. Not only occupants of dugouts were thus gassed but a number of nurses and doctors were gassed while working in closed rooms over patients suffering from mustard gas poisoning. Even under the conditions of warfare existing where the Americans were generally in action, the quantity of chloride of lime required amounted to several hundred tons per month which had to be shipped from the United States. Chloride of lime was also very convenient to have at hand around shell dumps for the purpose of covering up leaky shells, though rules for handling mustard gas shells usually prescribed that they be fired and where that was not practicable to bury them at least five feet under the surface of the ground. This depth was not so much for the purpose of getting rid of the gas as it was to get the shell so deep into the ground that it would not be a danger in any cultivation that might later take place.

MUSTARD GAS IN COLD WEATHER.

Much was learned toward the end of the war about ways of getting through or around areas infected with mustard gas. For instance if mustard gas be fired when the weather is in the neighborhood of freezing or somewhat below, it will remain on the ground at night with so little evaporation as not to be dangerous. The same will be true during the day time if the weather is cloudy as well as cold. If, however, the days are bright and the nights cold, mustard gassed areas can be safely crossed by troops at night provided care is taken in brush and bushes to protect the feet and clothing from the liquid splashed on bushes. If the sun comes out warm in the morning such areas may be quite dangerous for three to four hours following sunup and indeed for the greater part of the day. Quite a large number of casualties were ascribed to this fact in the heavy attack on the British front west of Cambrai just prior to the great German drive against Amiens March 21, 1918.

DEGASSING UNITS.

Since mustard gas has a greatly delayed action it was found that if men who had been exposed to it could be given a thorough bath with soap and water within a half hour or even a full hour, the mustard gas burns would be prevented or very greatly reduced in severity. Accordingly degassing units were developed consisting essentially of a 5 ton truck with a 1200 gallon water tank, fitted with an instantaneous heater and piping to connect it to portable shower baths. Another truck was kept loaded with extra suits of

underclothing and uniforms. These degassing units were to be provided at the rate of two per division. Then, in the event of a mustard gas attack anywhere in the division, one of these units would be rushed to that vicinity and the men brought out of the line and given a bath and change of clothing as soon as possible. At the same time they were given a drink of bicarbonate of soda water and their eyes, ears, mouth and nasal passages washed with the same.

PROTECTING FOOD FROM MUSTARD GAS.

It was very early learned that mustard gas, or minute particles of the liquid gas settling on food, caused the stomach to be burned if the food were eaten, just as the eyes, lungs and skin of the body are burned from gas in the air. This made it necessary then to see that all food liable to exposure to mustard gas attacks was protected, and tarred paper for box linings or tops was found by the Gas Service to furnish one of the cheapest and most available means of doing this.

ALARM SIGNALS.

Numerous, indeed, were the devices invented at one time or another with which to sound gas alarms. The English early devised the Strombos horn, a sort of trumpet operated by compressed air contained in cylinders carried for that purpose. Its note is penetrating and can be heard, under good conditions, for three or four miles. When cloud gas attacks, which occurred only at intervals of two to four months, were the only gas attacks to be feared, it was easy enough to provide for alarm signals by methods as cumbersome and technically delicate as the Strombos horn.

With the advent of shell gas in general, and mustard gas in particular, the number of gas attacks increased enormously. This made it not only impossible, but inadvisable also, to furnish sufficient Strombos horns for all gas alarms; as gas shell attacks are comparatively local. In such cases if the Strombos horn is used to give warning it causes troops who are long distances out of the area attacked to take precautions against gas with consequent interference with their work or fighting.

To meet these local conditions metal shell cases were first hung up and the alarm sounded on them. Later steel triangles were used in the same way. At a still later date the large policeman's rattle, well known in Europe, was adopted and following that the Klaxon horn. As the warfare of movement developed the portability of alarm apparatus became of prime importance. For those reasons the Klaxon horn and the police rattle were having a race for popularity when the Armistice was signed.

A recent gas alarm invention that gives promise is a small siren-like whistle fired into the air like a bomb. It is fitted with a parachute which keeps it from falling too rapidly when the bomb explodes and sets it free. Its tone is said to be very penetrat-

ing and to be quite effective over an ample area. Since future gas alarm signals must be efficient and must be portable the lighter and more compact they can be made the better, and hence the desirability of parachute whistles or similar small handy alarms.

ISSUING NEW MASKS.

One of the problems that remained unsolved at the end of the war was how to determine when to issue new boxes, or canisters, for masks. One of the first questions asked by the soldier is how long his mask is good in gas, and how long when worn in drill where there is no gas. This information is of course decidedly important. Obviously, however, it is impossible to tell how long a canister will last in a gas attack, unless the concentration of gas is known, - that is, the life of the box is longer or shorter as the concentration of gas is weak or heavy.

A realization of this need led mask designers to work very hard long before the necessity for comfort in a mask was as fully realized as it was at the end of the war, to increase the length of life of the canister. To get longer life they increased the chemicals and this in turn increased the breathing resistance thereby adding to the discomfort of the soldier when wearing the mask. Finally, however, it was found that in the concentration of gas encountered on an average in the field, the life of the comparatively small American boxes was sufficient to last fifty to one hundred hours, which is longer than any gas attack or at least gives time to get out of the gassed area.

The British early appreciated the necessity of knowing when boxes should be replaced. They accordingly devised the scheme of furnishing with each mask a very small booklet tied to the carrying case in which the soldier could not only enter a complete statement of the time he had worn the mask but also the statement as to whether it was in gas or for drill purposes only. The soldier was then taught that if he had worn the mask, say for forty hours, he should get a new box. But the scheme didn't work. In fact, it was one of those things which foresight might have shown wouldn't work. Indeed, any man who in the hell of battle can keep such a record completely, should be at once awarded a Distinguished Service Medal.

As gas warfare developed not only were all kinds of gas shells sent over in a bunch but they were accompanied by high explosive, shrapnel and anything else in the way of trouble that the enemy possessed. A man near the front line, under those conditions, had all he could do and frequently more than he could do, to get his mask on and keep it on while doing his bit. Consequently he had no time, even if he had the inclination, to record how long he had worn the mask in the various gases.

In this connection, after the Armistice was signed we in the field were requested to obtain for experimental purposes 10,000 canisters that had been used in battle. Each was to be labeled with the length of time it had been worn in or out of gas, and if in gas,

the name of each gas and the time the mask was worn in it. This request is just a sample of what is asked by those who do not realize field conditions. One trip to the front would have convinced the one making the request of the utter impossibility of complying with it, for really no man knows how long he wears a mask in gas. With gas as common and as difficult to detect (when intermingled with high explosive gases and other smells of the battle field) as it was at the end of the war, each man wore the mask just as long as he could, simply as a matter of precaution.

Before hostilities ceased we were trying out a method of calling in say fifty canisters per division once a week for test in the laboratory. If the tests showed the life of the canisters to be short new canisters would be issued. While we did not have opportunity to try out this plan, it gave promise to being the best that could be done. With gas becoming an every day affair, the only other alternative would seem to be to make issues of new boxes at stated intervals. On the other hand there are no definite records of casualties occurring from the exhaustion of the chemicals in the box. Undoubtedly some did occur, but they were very, very few. In nearly all cases the mask got injured, or the box became rusted through before the chemicals gave out.

TONNAGE AND NUMBER OF MASKS REQUIRED.

It will probably be a shock to most people to learn that with more than two million men in France we required nearly 1500 tons of gas material per month. This tonnage was increasing, rather than decreasing, to cover protective suits, gloves, pastes, and chloride of lime, as well as masks. The British type respirator was estimated to last from four to six months. The active part of the war, in which the Americans took part, was too short to determine whether this was correct or not. The indications were, however, that it was about right, considering rest periods and fighting periods.

With the new American mask, with its much stronger and stiffer face material, the chances are that the life will be considerably increased although the more constant use of the mask will probably offset its greater durability. A longer life of mask would of course be a decided advantage as it would not only reduce tonnage, but would reduce manufacturing and distribution as well. The estimates on which we were working at the end looked forward to requiring from the United States about one-third pound per man per day for all troops in France, in order to keep them supplied with gas defense material and with the gases used offensively by gas troops. All gas shell, hand grenades, etc., used by other than gas troops required tonnage in addition to the above.

SMOKE.

Smoke was rapidly becoming one of the most important new developments in warfare. While it had been known for many years to

have a value for screening attacking parties and to stop observation, its full development along this line was only being approached when the war closed. White phosphorus, because of the denseness and capacity of the smoke, together with the ability of the phosphorus to burn in the open, wet or dry, makes it the most valuable of all substances for this purpose. It is used in hand and rifle grenades, in shells of nearly all calibers, from three to six inch and in bombs fired from trench mortars by gas troops. Other smoke materials were used in candles weighing two to four pounds, or in large cylinders weighing up to ninety or one hundred pounds. These were various sulphur and ammonia compounds as well as an ammonia and titanium chloride mixture invented in the United States to be carried in a so-called knapsack. This knapsack gave promise of being very effective. These last materials can of course only be used where it is desired to put up a screen close to ones own trenches or at other points that men can readily reach.

In addition to the above materials certain chlorides, as titanium or silicon tetrachloride were being proposed for artillery shell. These appear excellent but do not have the continuing quality that burning phosphorus possesses. Phosphorus being a solid is broken up, when the shells burst into larger or smaller fragments, depending on the amount of explosive used. This quality, therefore, is capable of considerable control, so that the particles may be made to burn for ten minutes to half an hour and thus keep up the smoke screen.

There is really no limit to the uses to which smoke can be put. It has been used to hide the approach of a gas cloud, to simulate a gas cloud, and to mix with the gases themselves. It can be used to screen attacking troops, to screen artillery, and in numberless other ways. This is a field in which Yankee ingenuity should be exercised as it will make a great saving in lives and aid tremendously in all defensive and offensive tactics. Smoke needs to be studied in connection with the use of every other arm of the service, whether it be infantry, artillery, tanks, gas troops or aeroplanes.

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